CONTRIBUTIONS TO PALEONTOLOGY

FOSSIL VERTEBRATES FROM WESTERN NORTH AMERICA AND MEXICO

FURLONG · HALL · DAVID · WALLACE · HOWARD

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Remington Kellogg

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FOSSIL VERTEBRATES FROM WESTERN NORTH AMERICA AND MEXICO

E. L. Furlong
Lore Rose David
E. Raymond Hall
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Hildegarde Howard

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CONTRIBUTIONS TO PALEONTOLOGY

I

The Pleistocene Antelope, Stockoceros conklingi, from San Josecito Cave, Mexico

E. L. Furlong

With five plates

[ISSUED FEBRUARY 3, 1943]

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The Pleistocene Antelope, Stockoceros conklingi, from San Josecito Cave, Mexico

INTRODUCTION

Excavations in the Pleistocene deposits of San Josecito Cave, in southern Nuevo León, Mexico, have been carried on by Dr. Chester Stock and his associates of the California Institute of Technology during the past few years. Studies relating to the fossil mammals and birds found in this deposit are now in progress. The antilocaprid specimens, abundant in the collection, have been assigned to the writer for special investigation.

In an examination of the cave material it has been possible to record data on the growth changes in the horn cores, as well as on the variability of other structural parts. Because of their abundance and good preservation, the antelope remains have likewise given opportunity to prepare a mounted skeleton—the first to be made of *Stockoceros*. On the basis of the mount, a life-size restoration has been made by Mr. William Otto.

I desire to express my thanks to Dr. Childs Frick for his sustaining interest in the research on fossil antilocaprids, and to Dr. John C. Merriam for support in bringing this contribution to completion.

Tetrameryx (Stockoceros) conklingi Stock

Syn.—Tetrameryx onusrosagris Roosevelt and Burden.

Historical Review

Tetrameryx shuleri was first described by R. S. Lull in 1921. This extinct species of antelope from the Pleistocene deposits of the Dallas sand pits of Texas is known on the basis of the horn cores of one side, and the maxillary with premolar and molar teeth. Nine years later Stock (1930) described *T.? conklingi* from the Quaternary of Shelter Cave, New Mexico, referring the species tentatively to Lull's genus. The skull material on which this species was based represents a young animal, and a similar stage of development is indicated by a second horn core figured in Stock's paper. In a later paper, additional material of this antelope was described by Stock (1932), who referred the species definitely to *Tetrameryx*.

Roosevelt and Burden in 1934 described the species *T. onusrosagris* from the Pleistocene of the Papago Spring Cave, Arizona, distinguishing it from the New Mexican *T. conklingi* by the larger size of the horn core. Frick (1937) in his large work on the fossil horned ruminants of America relegated both *T. conklingi* and *T. onusrosagris* to the subgenus *Stockoceros*. Two years later Colbert and Chaffee (1939) published a more comprehensive and detailed account of the *Tetrameryx* remains from Papago Spring Cave. In this report they continue to recognize *T. onusrosagris* as specifically distinct from *T. conklingi,* not only because of larger size but also because of the more divergent horn cores of the former. No mention is made of a type of horn core from this locality like that seen in *T. shuleri,* that is, with the posterior core decidedly longer than the anterior. As a matter of fact, the only horn core which is apparently somewhat comparable in this character with that of *T. shuleri* is seen in the species *T. irvingtonensis,* described by R. A. Stirton (1939) from early Pleistocene deposits near Irvington, Alameda County, California.

Thus far, with the exception of the Arizona cave locality, no site has furnished sufficient material of the fossil antilocaprid *Tetrameryx* to permit a study of the growth changes in the horn cores. The collection from San Josecito Cave makes this kind of study possible, and the present paper attempts to review the changes in the horn cores and in certain skeletal parts. At least 50 individuals are represented by skulls or skull parts from the deposits of San Josecito. Limb bones are even more abundant because of their compact structure.

Growth Stages in Horn Cores

Differences due to age are readily discernible in the horn cores, in the dentition, and in skeletal parts. Those due to sex are less apparent.

Utilizing not only material from San Josecito Cave, but also specimens from Shelter Cave, New Mexico, and Papago Spring Cave, Arizona, the following sequential stages in the development of horn cores can be demonstrated:

C.I.T. no. 3013 (pl. 1, figs. 1, 1*a*). Dorsal part of skull with left orbit, maxillaries with teeth, and left ramus with teeth. Milk dentition, open sutures, and small growth of horn core indicate immature individual not more than a year old.

L.A.M. no. 174 (pl. 1, figs. 2, 2*a*). Type of *Tetrameryx conklingi,* from Shelter Cave, New Mexico. Cranial part of skull with horn cores and orbits. Age of this individual approximately 2 years.

C.I.T. no. 3165 (pl. 1, fig. 4). Fragment of frontal with right horn core and interdorsal part of orbit. This individual is more mature than no. 3013.

L.A.M. no. 208 (pl. 1, fig. 5). Fragment of frontal with left horn core and posterodorsal part of orbit. This individual from Shelter Cave, New Mexico, approximates in age no. 3165.

C.I.T. no. 3166. Fragment of right frontal with horn core and dorsal part of orbit. Comparable in size and age with L.A.M. no. 174.

C.I.T. no. 3005 (pl. 1, figs. 3, 3*a*). Fairly complete skull of a young adult. Occipital sutures not fused.

C.I.T. nos. 3004, 3164 (pl. 2, figs. 1, 1*a*, 2, 2*a*). Adult skulls.

C.I.T. nos. 2928, 3006, 3007, 3009, 3010 (pl. 3). Crania of older individuals than those represented by skulls listed above.

F.A.M. no. 42539 (pl. 2, figs. 3, 3*a*). Large part of skull of *T. onusrosagris* Roosevelt and Burden. Comparison of this skull with the old adult specimens listed above from San Josecito Cave shows no specific distinction between the former and the latter. On the contrary, a review of the present series demonstrates a gradation from the type of horn core found in the young to those with more divergent tines found in older animals. Thus there appears to be no valid reason for regarding *T. conklingi* and *T. onusrosagris* as specifically distinct.

A persistent absence of the type of horn core characteristic of *Tetrameryx shuleri* in the collections from Shelter Cave and San Josecito Cave, and apparently also in the collection from the Papago Spring Cave, where only horn cores with tines of subequal length are found, makes it reasonable to assume that *Stockoceros* is at least subgenerically distinct from *Tetrameryx.* Still larger collections than those now available may demonstrate an occasional variant core like that in *T. shuleri.* On the other hand, it does not appear justifiable to regard this kind of horn core as a sport, for a similar structure occurs in *T. irvingtonensis.* An interesting parallelism with the appearance of the horn core in *Stockoceros* is seen in the living antelopine form *Tetraceros quadricornis* of India.

Attitude and Degree of Bifurcation of Horn Core

The attitude of the horn cores in relation to the sagittal plane changes with age. In young individuals the horn cores are erect, but as age increases they tilt outward from the sagittal plane, and this inclination becomes more pronounced in older forms. The position and shape of the tines also undergo change with age (pl. 3, figs. 1, 3*a*). In young animals the front tine is somewhat heavier than the hind one, but is in anteroposterior alignment with it. This position changes with frontal growth, and the anterior tine takes on greater inclination than the rear tine.

With an advance in growth and height of the horn-core pedicel, the broad U-shaped saddle between the tines in fawns changes to a more sharply V-shaped notch in adults. This feature is variable and is apparently due to an anteroposterior thickening of the basal parts of the tines and a spreading of the distal ends with continued growth.

The pedicel is relatively thin in youth, thickens anteriorly with growth of the front tine above the anterodorsal orbital rim, and remains relatively thin and flat at the base of the rear tine above the dorsoposterior rim of the orbit. The flat surface extends dorsally into the rear tine and produces the oblate section of the rear tine, the anterior tine remaining round or oval in cross section.

The texture of the bone in the horn cores changes little in surface density with age, and remains spongy at the tip as in *Antilocapra americana.*

Rami

Left rami represent more than 80 individuals, and the large number of detached teeth of both the right and left sides of the jaw gives evidence of disintegration of many specimens. The enamel pattern in individual lower teeth is remarkably uniform throughout the series of specimens. An index of the relative growth of the jaw in *T. conklingi* is expressed by the proportion, length of cheek-tooth row to length of diastema between I_3 and P_2.

In 28 adult rami the average length, P_2 to M_3, is 64.0 mm.; the average length of the diastema between I_3 and P_2 is 55.6 mm. It would appear that the average length of the diastema is approximately 10 mm. less than that of the cheek-tooth row. This relation varies, however, with the age of the individual. In older individuals the length of the diastema tends to equal that of the cheek-tooth row. In some specimens the measurements are equal; rarely, the length of the diastema exceeds by a millimeter or two that of the cheek-tooth row.

The average depth of the jaw as measured from the margin of the middle alveolus of M_3 to the ventral border of the mandible, based on 24 specimens, is 25.7 mm.; maximum 29.0 mm., minimum 22.5 mm.

Twelve rami have deciduous teeth or their alveoli. In the youngest, the length of the tooth row as measured on the margins of the alveoli does not exceed 49.0 mm.

In specimens which approach maturity or in which p_4 is about to be shed, the length of the tooth row does not exceed 70.1 mm., and the length of the diastema does not exceed 56.0 mm.

Limb Elements

Appendicular parts of the skeleton show variations due to age. Since the metacarpals are among the most abundant elements in the collection and represent at least 161 individuals, they furnish excellent information as to range in size within a single species.

A series of 92 adult metacarpals range in length from a minimum of 150.0 to a maximum of 202.0 mm. In this series the most apparent break lies between a specimen 163.0 mm. long and one 169.0 mm. long. The shorter bones belong to young individuals, although in these the epiphyses are not separated from the shafts. In 18 metacarpals belonging to fawns, the distal epiphyses are absent. Of these, the longest is 168.0 mm., the shortest range from 99.5 to 137.0 mm. The proximal articular ends are always present except in the very young, where the fusion of the third and fourth metapodials is not complete. In specimens of minimum length the shafts of the third and fourth metacarpals are separate throughout the entire median line of contact.

Because of their compact structure, the astragali are among the most resistant elements in the skeleton and therefore the most numerous in the collection. Astragali of the right pes number 174. These specimens show only minor differences in size and proportions. The calcaneum is represented by 136 specimens of the left pes. In this series the length varies from 70 to 85 mm.

Mounted Skeleton

The skeleton shown in plate 5, figure 1 is the first mounted specimen of *Stockoceros conklingi*. The comparative measurements of this animal are given below. The vertebral formula is 7-13-6-4-9. Occasionally the last lumbar vertebra is joined at the side and by the neural spine with the first sacral vertebra. In general, the appearance of the skeleton is like that of the modern pronghorn, but the limbs are slightly heavier, the lower segments of the limbs shorter, and the ungual phalanges relatively stouter. The restoration of this animal by William Otto, shown in plate 5, figure 2, shows a similarity to the existing pronghorn, but although *Stockoceros* is approximately as long as the latter, its height is distinctly less. More obvious differences between the two are seen of course in the horn cores.

Comparative measurements (in millimeters) of skeleton

	Stockoceros conklingi C.I.T. no. 3227	*Antilocapra americana* L.A.M. no. M803
Height measured to top of horn core	1075	1270
Height measured to top of occipital part of skull	986	1143
Shoulder height measured to top of scapula	755	910
Height measured to top of neural spine of third thoracic vertebra	778	945
Height measured to top of crest of ilium	782	880
Length from tip of premaxillary to end of tail (projected on a horizontal line)	1142	1150

LITERATURE CITED

COLBERT, E. H., and R. G. CHAFFEE. 1939. A study of *Tetrameryx* and associated fossils from Papago Spring Cave, Sonoita, Arizona. Amer. Mus. Novitates No. 1034. 21 pp., 12 figs.

FRICK, C. 1937. Horned ruminants of North America. Bull. Amer. Mus. Nat. Hist., vol. 69. xxviii + 669 pp., 68 figs.

LULL, R. S. 1921. Fauna of the Dallas sand pits. Amer. Jour. Sci., vol. 2, pp. 163-167, figs. 2, 3.

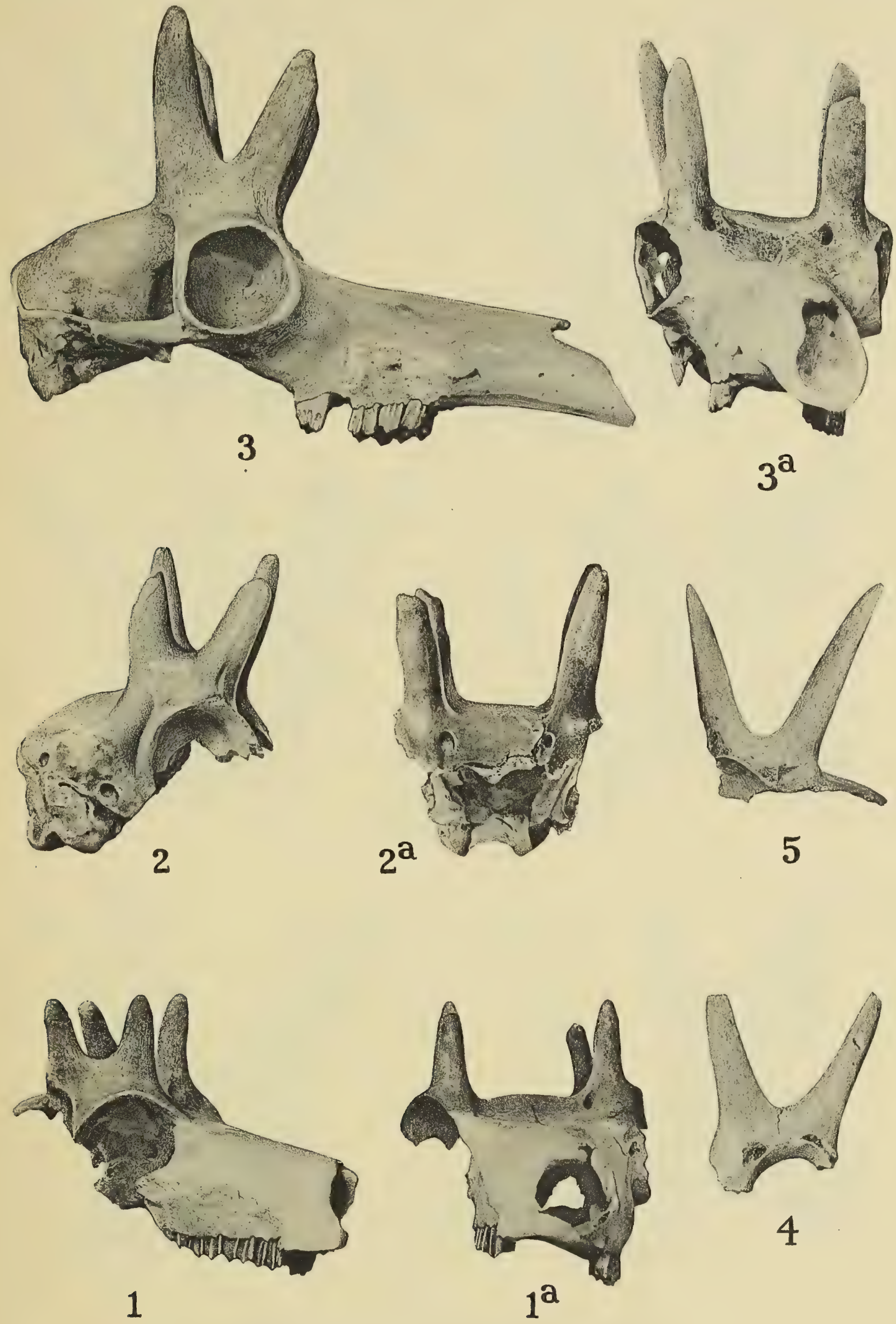
ROOSEVELT, Q., and J. W. BURDEN. 1934. A new species of antilocaprine, *Tetrameryx onusrosagris,* from a Pleistocene cave deposit in southern Arizona. Amer. Mus. Novitates No. 754. 4 pp., 1 fig.

STIRTON, R. A. 1939. Cenozoic mammal remains from the San Francisco Bay region. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 24, no. 13, pp. 399-402.

STOCK, C. 1930. Quaternary antelope remains from a second cave deposit in the Organ Mountains, New Mexico. Los Angeles Mus. Publ. No. 2. 18 pp., 3 figs.

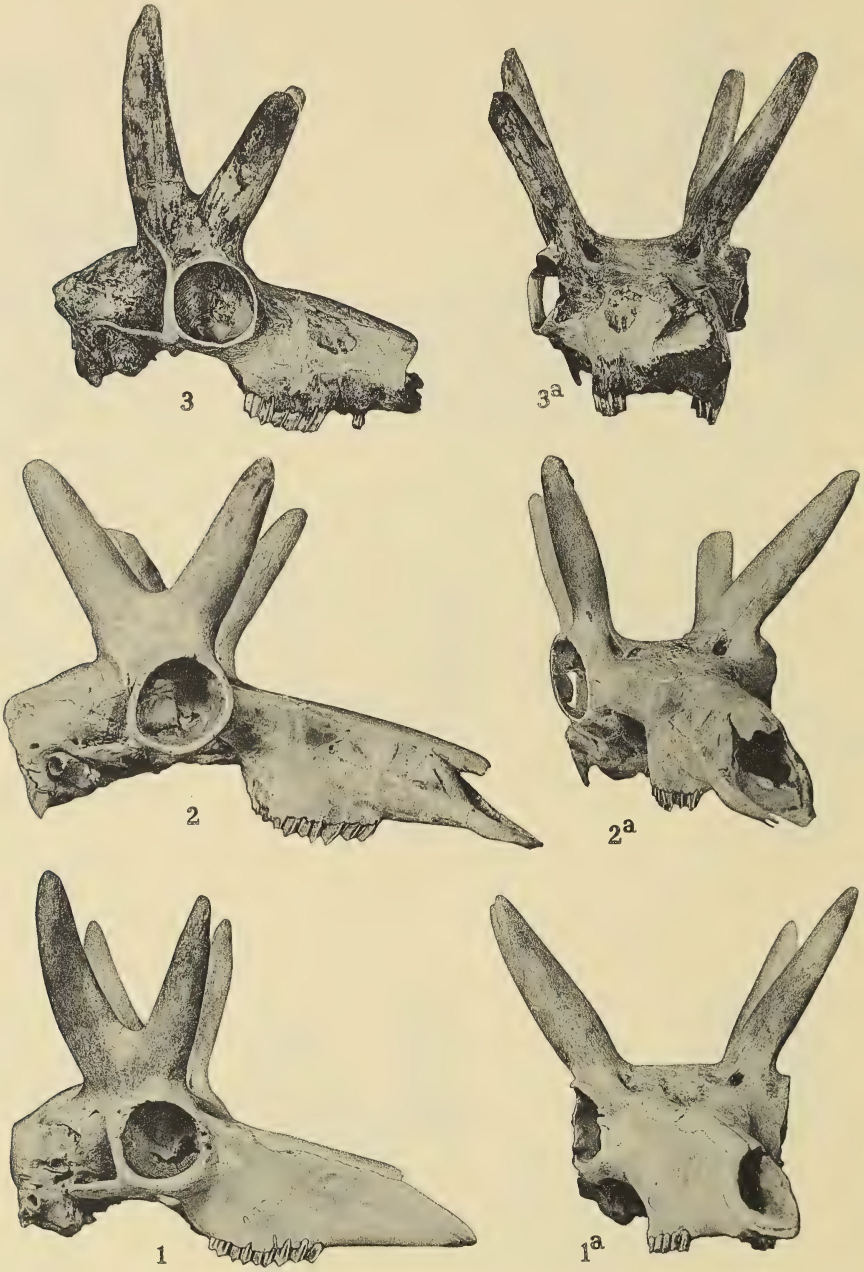
——— 1932. A further study of the Quaternary antelopes of Shelter Cave, New Mexico. Los Angeles Mus. Publ. No. 3. 45 pp., 11 figs.

PLATES



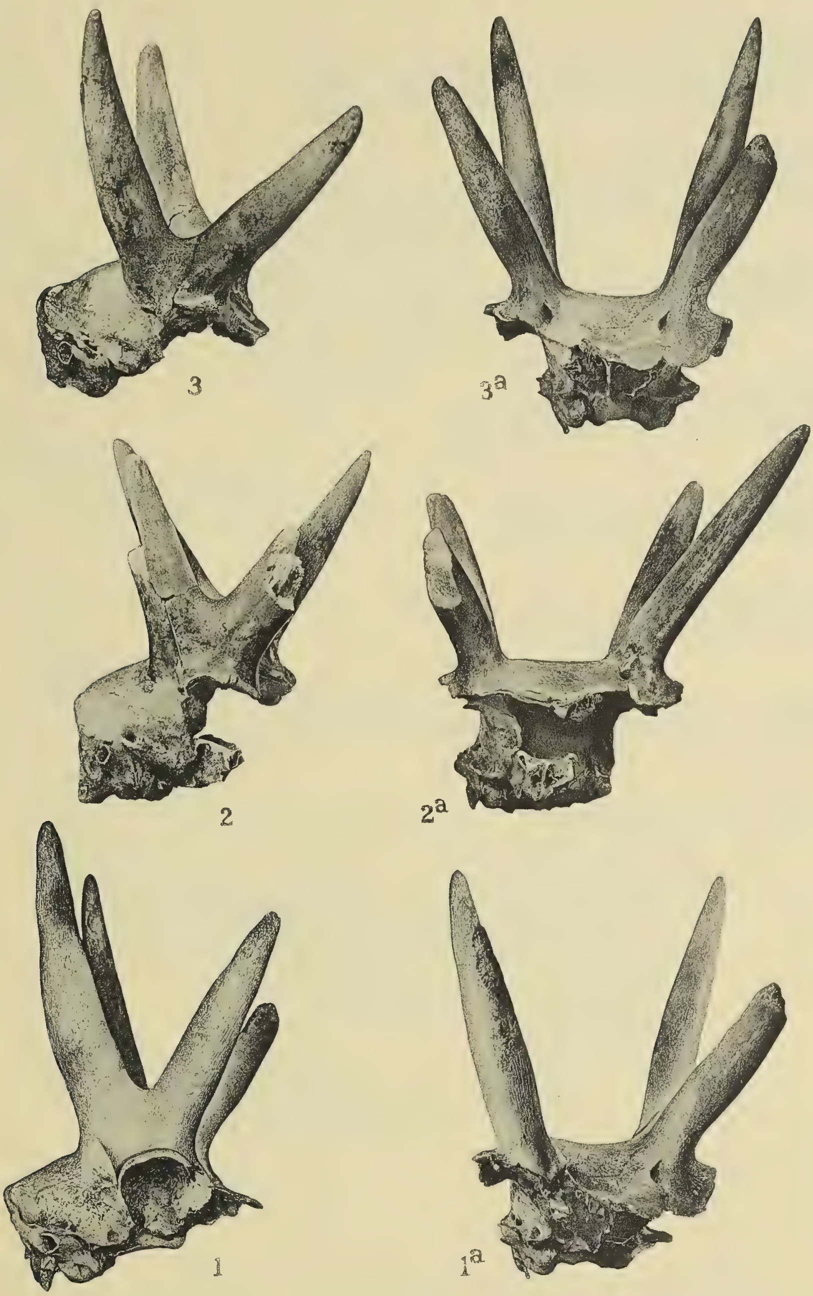
Tetrameryx (Stockoceros) conklingi Stock

Horn cores of young or youthful animals. Figs. 1, 1*a*, Calif. Inst. Tech. Vert. Pale. Coll. no. 3013; figs. 2, 2*a*, Los Angeles Mus. Coll. no. 174, type specimen; figs. 3, 3*a*, C.I.T. no. 3005; fig. 4, C.I.T. no. 3165; fig. 5, L.A.M. no. 208. Outer and dorsal views; all figures × 0.35. C.I.T. specimens from San Josecito Cave, Mexico. L.A.M. specimens from Shelter Cave, New Mexico.



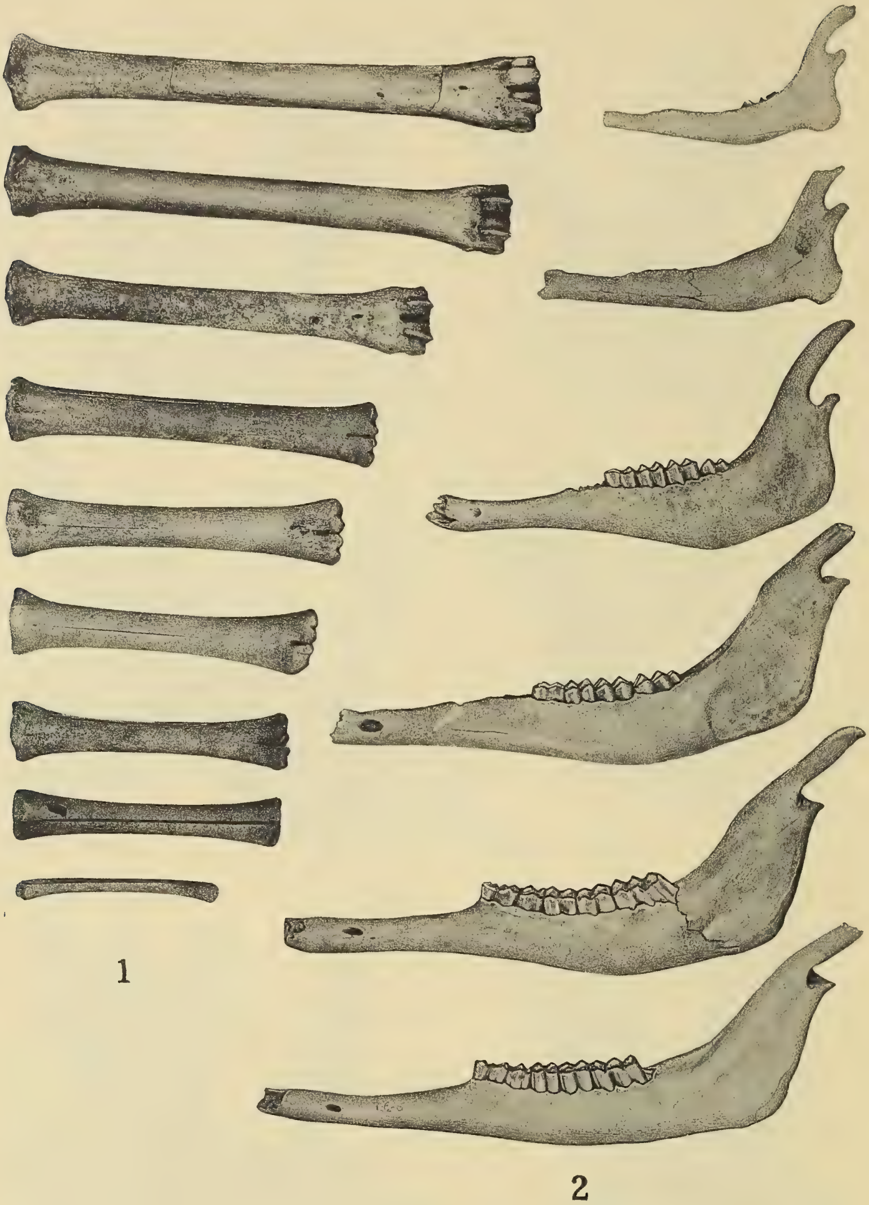
Tetrameryx (*Stockoceros*) *conklingi* Stock

Horn cores of young adult or adult specimens. Figs. 1, 1*a*, C.I.T. no. 3004; figs. 2, 2*a*, C.I.T. no. 3166; figs. 3, 3*a*, Frick: Amer. Mus. no. 42539. Outer and dorsal views; all figures approx. × 0.25 C.I.T. specimens from San Josecito Cave, Mexico; F.A.M. specimen from Papago Spring Cave, Arizona.



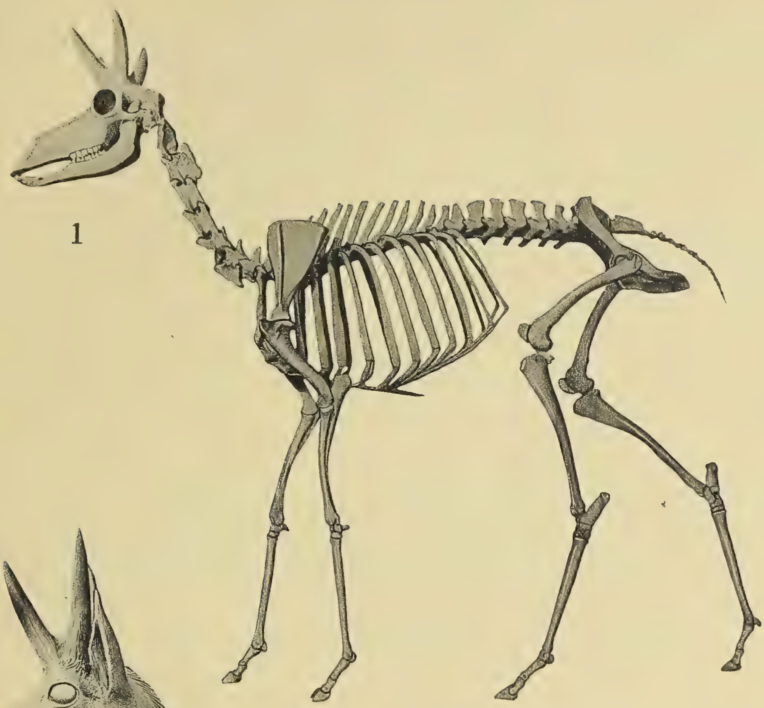
Tetrameryx (*Stockoceros*) *conklingi* Stock

Horn cores of mature individuals, showing variations in bifurcation and attitude. Figs. 1, 1*a*, C.I.T. no. 2928; figs. 2, 2*a*, C.I.T. no. 3007; figs. 3, 3*a*, C.I.T. no. 3006. Outer and dorsal views; all figures approx. × 0.25 San Josecito Cave, Mexico.



Tetrameryx (*Stockoceros*) *conklingi* Stock

Fig. 1, series of metacarpals representing stages of development from young to adult; fig. 2, similar series of rami. All figures × 0.35. San Josecito Cave, Mexico.



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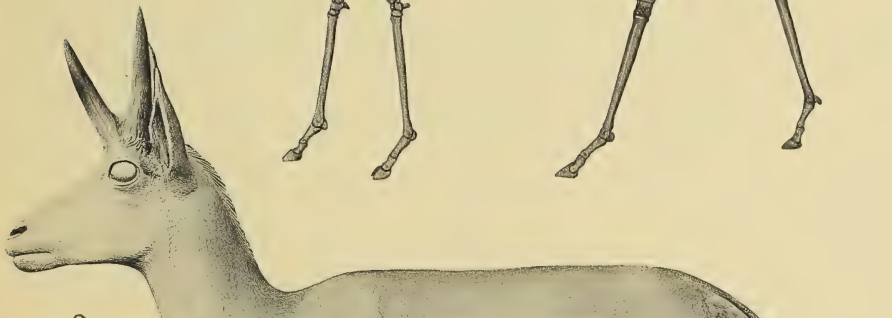

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Tetrameryx (*Stockoceros*) *conklingi* Stock

Fig. 1, mounted skeleton of mature individual as seen from left side, C.I.T. no. 3227; × approximately 0.08. Fig. 2, restoration by William Otto, based on skeleton shown in figure 1. San Josecito Cave, Mexico.

II

A New Genus of American Pliocene Badger, With Remarks on the Relationships of Badgers of the Northern Hemisphere

E. Raymond Hall

With two plates and two text figures

[ISSUED JULY 18, 1944]

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A New Genus of American Pliocene Badger, With Remarks on the Relationships of Badgers of the Northern Hemisphere

INTRODUCTION

Through the kindness and scientific interest of Mr. Albert L. Brown, of Burns, Oregon, Dr. Chester Stock, of the California Institute of Technology, has been granted the loan of a fossil skull of a badger. The specimen was found by Mr. Brown in Tertiary deposits exposed on Stinking Water Creek in northeastern Harney County, Oregon. Fossil remains of mammals were collected in this general area in 1931 by E. L. Furlong, E. R. Inglee, and C. Stock. R. W. Wilson (1937) gave a list of the rodents in this collection. These and other kinds of mammals comprise a fauna seemingly more closely related to that from the Thousand Creek beds in northern Nevada, which are Middle Pliocene, than to any other fauna yet known.

The badger skull, which Dr. Stock has generously permitted the writer to study, is by far the best American Tertiary material of its group so far found. Fortunately it retains most of the dentition in an excellent state of preservation. The specimen has special significance because it sheds light on the generic status of *Taxidea nevadensis,* described by Butterworth from the Thousand Creek Pliocene, and makes possible for the first time a satisfactory comparison of the skull of the Pliocene badger of America with the skulls of *Parataxidea,* described by Zdansky from the later Tertiary of China. The skull from Oregon is clearly quite distinct from that of *Parataxidea,* the modern *Taxidea,* or any other named genus. This badger from the North American Pliocene is therefore recognized under the following generic name:

PLIOTAXIDEA, new genus

Genotype. Taxidea nevadensis Butterworth, Univ. Calif. Publ., Bull. Dept. Geol., vol. 10, p. 21, October 3, 1916. Middle Pliocene, Thousand Creek beds, Nevada.

Diagnosis. Skull with basilar length of about 65 mm., therefore a third to a half shorter than in *Taxidea;* cranium evenly convex dorsally and deepest at anterior end of parietals; facial angle steep, and dorsal outline of rostrum concave ("dish-faced"); tympanic bullae highly inflated, the length of one amounting to more than the length of upper tooth row (canine to molar inclusive); least distance between tympanic bullae less than length of P^2 and P^3; paroccipital process flattened and closely applied to tympanic bulla; hamular processes of pterygoids fused with, or touching, tympanic bullae; palate ending behind upper molars; dental formula, $\frac{3}{3?}, \frac{1}{1}\, \frac{3}{3?}, \frac{1}{2}$; premolars not overlapping; P^4 with well developed parastyle and well developed accessory cusp (hypocone) behind protocone; M^1 triangular in outline, with cusps arranged in rows transverse to long axis of skull; in M_1 trigonid a third longer than talonid, metaconid large, hypoconid and entoconid large, talonid cuspidate and not basined.

Remarks. The type specimen of *Taxidea nevadensis* Butterworth, from the Middle Pliocene of Thousand Creek, Nevada, consists of the four posterior teeth of the right lower jaw, with nondiagnostic parts of supporting bone (see pl. 2). The last three teeth are well preserved. In the specimen from Oregon, the corresponding teeth of the left lower jaw are present and in addition the second premolar, but M_2 and the talonid of M_1 are broken. As a result, comparison of these parts is not wholly satisfactory. Even so, it is ascertainable that the size and proportions of the talonid of M_1, and its size relative to the trigonid, are almost, and perhaps exactly, the same as in the type specimen of *T. nevadensis.* The undamaged teeth, namely P_3, P_4, and the anterior part of the trigonid of M_1, resemble those of the type specimen in all features judged to be of systematic worth. The resemblances mentioned above constitute the basis for regarding the skull from Oregon as conspecific with *Taxidea nevadensis* Butterworth.

The combined fossil material was relied upon in drawing up the diagnosis above. *Pliotaxidea* is judged to bear closer relationship to *Taxidea* than to any other genus. To offer sound opinion on the closeness of this relationship, as judged by the morphological similarities and dissimilarities of the two genera, it is necessary to recognize and exclude variations of nongeneric and nonspecific significance. Information of this kind is available for the genus *Taxidea.* Of it, at most two species are known. One is *T. mexicana,* known from a single find in deposits thought to be of Middle Pliocene age in Chihuahua, Mexico. The other species is *Taxidea taxus.* It is confined to North America, and in Recent time ranges from the eastern margin of the Great Plains westward to the Pacific coast, and in a north-and-south direction from within the southern part of western Canada well onto the tableland of Mexico (for more precise data on range see Hall, 1936, pp. 77–83). In this area of western North America five geographic races (subspecies) are recognized. All the fossil records fall within the geographic area mentioned as inhabited by the species in Recent time, except one. It is from the Pleistocene of Maryland, and was made the basis of the name *Taxidea marylandica* Gidley and Gazin. Two other names, *Taxidea sulcata* Cope and *Taxidea robusta* Hay, were based on remains from deposits of Pleistocene age, but, as previously noted (Hall, *op. cit.,* pp. 79–82), the remains of all three are to the writer indistinguishable from those of living subspecies of the Recent *Taxidea taxus,* of which the names based on Pleistocene fossils are arranged as synonyms.

Variation in size between the five Recent subspecies is considerable, individuals of the southern subspecies being the smallest. For example, the skull of an adult of *Taxidea taxus sonoriensis* from Mexico, of a size that is average for the subspecies, is by actual weight hardly two-thirds as heavy as that of an individual of *Taxidea taxus taxus* that is average in size for this subspecies in Alberta, Canada. Also, there is variation in size between the sexes. Linear measurements of a series of equal age of each sex from Elko County, Nevada, reveal that females are smaller by 10 per cent in external dimensions, 8 per cent in the skull, and 3 per cent in the teeth. Superimposed on these variations is the individual variation found among animals of the same age, sex, and geographic origin. In 20 males from a limited area in Nevada, variations in linear measurements of the three largest teeth (P^4, M^1, and M_1) range from 13 to 23 per cent. When one considers, in addition, the changes in bones which result from growth with increasing age of the individual, the quantitative variations within the species *Taxidea taxus* are seen to be relatively great. Nor is this all, for qualitative differences of an amazing sort are found even within a population of one subspecies. To illustrate: of cusps on the talonid of M_1 there may be 2, 3, 4, or 5. Figure 3 of plate 2 shows an individual with 4 cusps. Among 20 individuals of the same subspecies from Nevada, the entoconid and hypoconid are present in every specimen. Cusp 1 (see fig. 1) is present in 5 individuals, cusp 2 in 11, and cusp 3 in 9 individuals. Comparable variation exists in P^4 and M^1. This kind of variation is appropriately used in most other groups of Carnivora in differentiating between full species and genera. It will be evident, therefore, that the student must exercise unusual caution in designating as of specific or generic worth the morphological differences that he detects between the skull and teeth of one badger and the corresponding parts of other individuals. Geographic variation within a single species, plus sexual dimorphism and great range of individual variation, may account for many morphological differences.

With due regard to this need for careful discrimination, the following cranial and dental features are employed as probably of systematic worth in differentiating

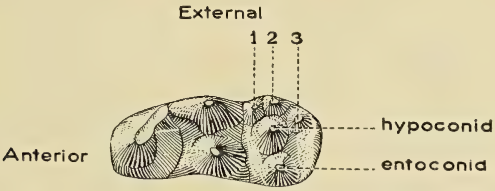


FIG. 1. Diagrammatic view of occlusal face of first right lower molar of *Taxidea,* to show cones which may be present on the talonid. × 2.

Pliotaxidea nevadensis from *Taxidea taxus:* skull of the former about two-fifths smaller in most linear dimensions; tympanic bullae actually about same size, therefore relatively larger (see fig. 2*a, b*); rostrum, in relation to remainder of skull, smaller; brain case, in relation to length of skull, deeper and more convex dorsally in longitudinal axis; P^4 with well developed parastyle (ordinarily lacking and never so well developed in *Taxidea*); M_1 with talonid longer in relation to trigonid, and with trigonid transversely wider in relation to its length (see pl. 2, figs. 2, 2*b*, 3); anterior teeth about half (in linear measurements) as large, but increasing in size posteriorly to a point where the last upper molar is only a tenth smaller. More precise data on the relative sizes of the teeth in the two genera as derived from measurements of a male *Taxidea taxus* (Univ. Calif. Mus. Vert. Zool. no. 37332, from Gondolfo Ranch, Lander County, Nevada) and the specimen of *Pliotaxidea* from Oregon are as follows: in the latter, the anteroposterior extent of I^3 is 46 per cent of that in *Taxidea taxus;* C^1, 58 per cent; P^2, 64 per cent; P^3, 68 per cent; P^4, 82 per cent; M^1, 90 per cent. A similar tendency to more nearly equal size of the back teeth is revealed in the lower jaw.

Many other differences between the specimens of *Pliotaxidea* and *Taxidea* are apparent, but in view of what has been stated with reference to the tremendous range of individual variation in the Recent species, it seems unwise to emphasize these additional differences; they may not be of systematic significance. Those regarded as of systematic worth are mentioned in the paragraph immediately preceding.

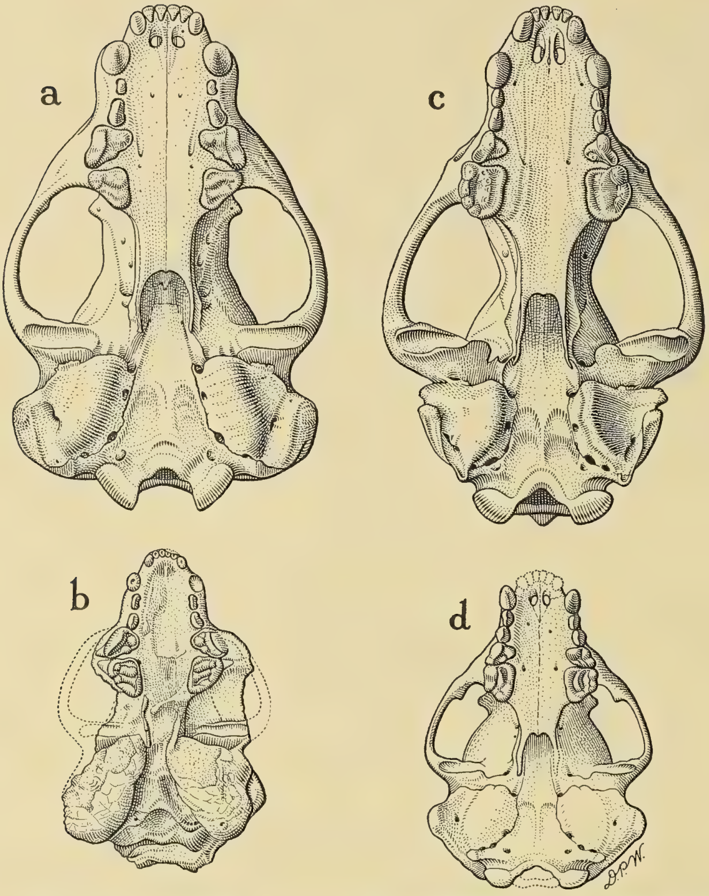


Fig. 2. Ventral views of skulls of four genera of badgers. *a, b,* New World badgers; *c, d,* Old World badgers. × ½.

a. Taxidea taxus (Schreber), Recent, sex?, Calif. Inst. Tech. no. O-45, from Oregon.

b. Pliotaxidea nevadensis (Butterworth), Pliocene, from Stinking Water Creek, northeastern part of Harney County, Oregon.

c. Meles meles Linnaeus, Recent, Univ. Calif. Mus. Vert. Zool. no. 34265, from Mas Grenier, Tarn-et-Garonne, France.

d. Parataxidea sinensis Zdansky, Pliocene?, from Shansi Province, China. Modified from Zdansky (1924, pl. 10, fig. 6).

Pliotaxidea nevadensis (Butterworth)

(Plate 1; plate 2, figures 2, 4, 5, 7, 9; text figure 2*b*)

Taxidea nevadensis Butterworth, Univ. Calif. Publ., Bull. Dept. Geol., vol. 10, pp. 21–24, fig. 1, October 3, 1916.

[*Parataxidea*] *nevadensis,* Zdansky, Palaeontologia Sinica, ser. C, vol. 2, fasc. 1, p. 52, 1924.

Taxidea, Stirton, Amer. Jour. Sci., ser. 5, vol. 32, p. 171, 1936. Hesse, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 24, p. 61, 1936.

Type. Fragment of right lower mandible bearing P_4, M_1, M_2, and part of P_3, Univ. Calif. Mus. Paleontology no. 22290 (pl. 2, figs. 2, 2*a,* 2*b*); from Thousand Creek

Pliocene, northern Nevada, Univ. Calif. Mus. Pal. locality 2744; obtained in summer of 1915.

Referred material. Skull and left lower cheek teeth (pl. 1; text fig. 2*b*) from Pliocene beds, Stinking Water Creek, northeastern Harney County, Oregon; obtained by Albert L. Brown.

Left P^4 lacking part of hypocone, Univ. Calif. Mus. Pal. no. 27130 (pl. 2, fig. 4); from Esmeralda beds (Pliocene), 7½ miles north of Chiatovich Ranch, Fish Lake Valley, Esmeralda County, Nevada; obtained in spring of 1925 by Annie M. Alexander and Louise Kellogg.

Anterior half of left P^4 (no. 30440), left M^1 (no. 30441), and left M_1 (no. 30442), Univ. Calif. Mus. Pal. (pl. 2, figs. 5, 7, 9); from Pliocene beds, 1½ miles southwest of Optima, Texas County, Oklahoma; collected in April 1929. See below under "Remarks" for additional account of this material, which Drescher (1939, p. 59) thinks may be of another species.

Diagnosis. See the diagnosis of the monotypic genus.

Range. Geological: Middle and Lower Pliocene. Geographical: Oklahoma northwest to Oregon.

Remarks. The P^4 from the Esmeralda beds differs from that in the specimen from Oregon only in that the parastyle is more a transverse ridge than a discrete rounded cusp. This difference is less than that resulting from individual variation in comparable dental structures of the Recent *Taxidea taxus.*

Some uncertainty exists about the identification of the teeth from Oklahoma and the fossil material, mentioned below, from Mexico. The three teeth from Oklahoma are here tentatively referred to *Pliotaxidea nevadensis* because of their small size; well developed parastyle on P^4, and relatively long talonid on M_1. The broader heel on M_1 is a feature suggesting affinity instead with the Recent *Taxidea taxus.*

As early as 1936 (see Hesse, 1936, p. 61) the writer examined the fossil teeth from Oklahoma and was unwilling to identify them as of a species different from *Taxidea taxus* until there were available for comparison specimens of the Recent *Taxidea taxus berlandieri,* the southern subspecies, individuals of which are smaller than those of the northern subspecies. In 1938 or 1939 the writer took the same attitude with respect to the horizontal ramus of a right lower jaw and the distal end of a right humerus from deposits in Chihuahua, Mexico, which Drescher (1939, p. 57) made the basis for a new species, *Taxidea mexicana.* Two and a half months before Drescher proposed the name *Taxidea mexicana,* E. A. Goldman named from southern Sonora, Mexico, the Recent subspecies *Taxidea taxus sonoriensis,* characterized by small size.

Adequate material of the Recent *Taxidea taxus* from the southern part of its range is still not available, but two pertinent skulls of females from that region have been examined. These are Univ. Calif. Mus. Vert. Zool. no. 74807, from southern Arizona, and no. 74808, from Sonora, Mexico. Use of these two skulls in comparisons shows that only two of the six cranial characters mentioned by Drescher (*op. cit.,* p. 59) as diagnostic of his *T. mexicana* apply. The first of these two characters is the thinner ramus of the lower jaw near its anterior end, in the fossil specimen. The second is the shorter canine in the lower jaw (the diameter of the canine in one of the Recent specimens is less than in the fossil specimen). With a larger sample of the Recent animal, even these two differences might be found not to apply. In the distal end of the humerus Drescher found differences from individuals of the large, northern

Recent subspecies of *Taxidea taxus.* The lack of humeri of the small, southern Recent subspecies makes it impossible to say whether the same differences prevail. It is doubtful whether they do. In view of what has been pointed out, the writer chooses for the time being to allocate the Mexican material to the Recent subspecies *Taxidea taxus sonoriensis* Goldman.

Nevertheless, by analogy with what is known of lines of descent of other kinds of mammals, it is to be expected that the badger from the Recent and the badger from the upper part of the Pliocene would be at least specifically distinct. When specimens of badgers as complete as the one from Oregon are available from the Upper Pliocene beds of Oklahoma and from Sonora, Mexico, specific distinctness from the Recent badger will probably become apparent.

An important point in this connection is that if *T. mexicana* Drescher is found to be distinct from *T. taxus sonoriensis,* and if it is of Middle Pliocene age, *Pliotaxidea* of the Lower and Middle Pliocene cannot be regarded as directly ancestral to *Taxidea.*

Whatever the exact systematic position of these fragments from Oklahoma and Mexico, the animals concerned are clearly of the American *Pliotaxidea-Taxidea* line of descent, and not of the Asiatic *Parataxidea-Meles* line.

Discussion

In 1924 Zdansky named and described from the Pliocene of China a new genus of badger, *Parataxidea* (see fig. 2*d*). In comparing this with the American genus, *Taxidea,* he says (1924, p. 52):

> Nach Erwähnung der Ähnlichkeiten unserer Form mit *Taxidea* darf auch der Unterschiede nicht vergessen werden. Dieselben sind so schwerwiegender Natur, dass nicht daran gedacht werden kann, die neue Form in die Gattung *Taxidea* einzureihen. *Parataxidea,* wie ich die chinesische Form zu benennen vorschlage, erweist sich durch die Form der Bulla, das einfache For. lac. post., die Form von P^4 und M^1 sowie durch die Anzahl der Prämolaren primitiver als *Taxidea,* zeigt sich jedoch durch die Form der zweiten und dritten Prämolaren beider Kiefer höher spezialisiert als diese. Somit kann *Parataxidea* als Vorfahre von *Taxidea* nicht in Betracht kommen.

From the excellent Asiatic material that he had, Zdansky (*op. cit.*) named two species. Of these, *Parataxidea sinensis* evidently is the genotype. He refers to his new genus an earlier-named Old World badger, *Meles maraghanus* Kittl, from Persia, and also the American *Taxidea nevadensis* Butterworth from Nevada. Regarding the latter, Zdansky (*ibid.,* pp. 52–53) says in part:

> Butterworth hat wegen der Dürftigkeit seines Materiales keine neue Gattung aufgestellt, doch nun glaube ich, "*Taxidea*" *nevadensis* unbedenklich auf *Parataxidea* beziehen zu dürfen. Es ist das von besonderem Interesse, da wir hiemit eine der ganz spärlichen Raubtiergattungen der Hipparion-Fauna vor uns haben, die dem eurasiatischen Kontinente und Nord-Amerika gemeinsam sind. Wenn die gleich zu entwickelende Ansicht von der Abstammung der Gattung *Parataxidea* von den europäischen *Trochictis* richtig ist, so muss die chinesische Form älter sein als die amerikanische, die unterpliozänes Alter besitzt. Wir haben dann hier, wie bei

Indarctos Lagrelii (siehe diesen), ein Argument für das obermiozäne Alter der chinesischen Hipparion-Fauna an der Hand.

Now that more adequate material of the North American Pliocene badger is available, it is clear that different conclusions are to be drawn on some of the points mentioned by Zdansky. In the first place, *Taxidea nevadensis* Butterworth is not properly referable to *Parataxidea,* the Pliocene badger of the Old World, but is definitely more closely related to the Recent and Pleistocene *Taxidea taxus* of North America. Characters in which *Pliotaxidea* (= *Taxidea nevadensis*) differs from *Parataxidea* and at the same time resembles *Taxidea,* that support this view, are: construction (see illustrations) and larger size of P^4; larger size of P^4 in relation to M^1; triangular rather than quadrangular shape of M^1; arrangement of cusps in transverse rather than longitudinal rows on M^1; cuspidate rather than basined or semi-basined talonid of M_1; larger size of tympanic bullae, which actually are as large as in *Taxidea.* In the second place, fossil badgers cannot be used in the way Zdansky employs them to indicate greater age for the Hipparion fauna of China.

It should be repeated that it is the availability of more and better material of *Taxidea nevadensis* that has led to conclusions which differ from those of Zdansky. On the basis of the single specimen of the American Pliocene badger known when Zdansky wrote of it, any worker might also have drawn the conclusions that he did.

The point to be emphasized is that the two groups of badgers, one in North America, the other in Asia, were already distinct certainly well back in Pliocene time and probably in the Upper Miocene. Knowledge of this distinctness of the two stocks of badgers in the later Tertiary makes necessary some further minor revision of current views on the phylogeny and classification of the Mustelidae. The best summary of current opinions regarding relationships within the group is presented by Pilgrim (1933, p. 861). In his diagram or "phylogenetic tree" he evidently accepts Zdansky's (*op. cit.*) views on the congeneric relationships of Pliocene and late Miocene badgers of America and Asia. It now seems apparent that a more accurate presentation of relationships would be provided by placing *Parataxidea* on a branch from the main *Meles* stem and recognizing *Pliotaxidea* and *Taxidea* (all the American badgers) as of a stem separate from that of the Old World badgers. In the light of present knowledge, both stems should be regarded as related to *Trocharion* and the mephitine section of the family in about the manner that Pilgrim has suggested in his diagram referred to above. *Parataxidea* may not be directly ancestral to *Meles,* and *Pliotaxidea* may not be directly ancestral to *Taxidea,* but the known Tertiary specimens are close to their respective stem forms in the line of descent.

In the Pliocene and late Miocene of North America and Asia some kinds of carnivores were generically, and perhaps specifically, inseparable. An example in the Mustelidae (the family to which the badger belongs) is the wolverine, *Plesiogulo* (Zdansky, 1924, p. 38; Martin, 1928, p. 233). In Recent time, the wolverine (*Gulo luscus*) ranges much farther north in each continent than do the badgers (*Meles* in Asia, and *Taxidea* in North America). Therefore, if a land connection were now to be re-established across Bering Strait, an interchange of wolverines but not of badgers between Asia and North America would be expected. A similar difference in north-to-south distribution between these two groups may have existed also in Tertiary time. If so, this would in part account for the generic distinctness between badgers, and congeneric relationship of wolverines, in the two continents. It is of course by no means certain that the geographic ranges of the Tertiary wolverines and badgers differed in north-to-south extent as do the ranges of their living representatives. Neither is it certain that the climate over the land bridge was boreal; it may have been no cooler than in what we term the temperate region today. Also, there is the case of the ratel (*Mellivora*), which in the later Tertiary (*Eomellivora*) was generically, and perhaps specifically, identical in North America and Asia (see Zdansky, 1924, p. 61; Stock and Hall, 1933, p. 63). In Recent time *Mellivora* has a geographic range more southern even than those of the badgers. Therefore, on first consideration, the evidence provided by the ratel appears to be against, rather than in favor of, the suggestion that mustelid carnivores now of austral predilections were generically distinct in the two continents in the late Tertiary, whereas mustelids now of boreal predilections were congeneric. Indeed, such a generalization is unwarranted; but it seems desirable to point to these facts and possibilities, since they have a place in explaining the ranges of the three mustelid stocks just mentioned. Certainly the ratel and wolverine in the Tertiary were in general relatively unspecialized. Furthermore, they were not so distantly related as Pocock's estimate (1920*a,* p. 179) of the Recent kinds might lead one to suppose, or as Pilgrim's statement (1933, p. 862), but not his diagram (*ibid.,* p. 861), might suggest. The specialization shown by these two stocks is demonstrated by the highly sectorial dentition. Probably competition for subsistence existed where the two occurred together, since both were of about the same size and had similar dentitions. In any considerable area of the same land mass and over a long span of time, however, development along a particular line would be likely for only one type. In a sense the ratel appears to have been the loser in this competition; it died out in the New World, and in the Old World it was pushed off to, withdrew to, or continued to flourish in, the south.

It should be noted also that, whereas the dentition of the Recent *Gulo* shows a further development of the specialization already well shown in the Tertiary *Plesiogulo,* the dentition of the Recent *Mellivora* is less changed from that of the Tertiary *Eomellivora.* The change that has occurred in the latter appears to be more of a degenerative modification than one which better enables the animal to retain its place among carnivores with sectorial dentitions. In conformity with this evidence, the Recent ratel is almost omnivorous or, at any rate, subsists on smaller animals and a far more varied diet than the Recent wolverine.

Despite the Recent ratel's loss of ground in some directions, the basic pattern of its dentition, the dentition of *Eomellivora,* and that of both the wolverines are indicative of highly carnivorous food habits. The badgers, on the other hand, particularly the Tertiary genera, have dentitions that are modified in considerable degree from a purely flesh-eating pattern toward one adapted for feeding on a more varied diet, including insects. Evidence of an adaptation to insect foods includes the small but sharply pointed anterior premolars and small but highly cuspidate P^4. A close parallel to this dentition is that of the Recent striped skunk, *Mephitis,* more than half of whose food for the year, and all of it in some seasons, is composed of insects. The character of the occlusal faces of M^1 and of the heel of M_1 in the badgers (see pls. 1, 2) is useful to an insect-eater, but is even better adapted for an omnivorous diet which includes some insects. The area of crushing surface between M^1 and M_2 and the talonid of M_1 was actually about as large in the small Tertiary badgers as in the much larger living badgers. This crushing apparatus, reminiscent of that in the Suidae, Hominidae, and Ursidae, characterized the earliest known badgers and indicates for them a way of life that has changed little since probably the Miocene. The change which has taken place in the American badgers is a limited alteration in the direction of slightly more sectorial teeth. In most individuals of *Taxidea,* P^4 lacks the parastyle seen in *Pliotaxidea,* and the trigonid of M_1 is more bladelike and larger in relation to the talonid than in the latter genus. Despite this slight modification, the combination of insectivorous-omnivorous adaptations in the dentition is a long-time possession of the badger stock, just as the highly sectorial dentition has been a long-time possession of the wolverine stock. Application of this interpretation can be made to better advantage later on, after consideration of the tympanic bullae, a part of the auditory mechanism.

In Recent badgers the tympanic bullae are large. In the badgers of the late Tertiary the bullae were relatively even larger—actually about as large as in the living animals. As respects general size of skull, and probably of most other parts, Recent badgers are roughly twice as large in linear measurements as the Tertiary kinds, *Pliotaxidea* and *Parataxidea. Taxidea* weighs about 16 pounds as compared with probably 4 to 6 pounds for *Pliotaxidea.* The bullae are thin-walled, not cancellous as in some mustelids, for example *Mustela,* and the enclosed space serves as a resonating chamber. Faint sounds are intensified by mechanisms of this sort, and the implication is that the badger has acute hearing. Generally speaking, the advantage of acute hearing to mammals which live in unforested areas—plains, deserts, steppes—as *Taxidea* does, is either in detecting prey as an aid in capturing it, or in detecting enemies as an aid in eluding them. In the latter case acute hearing is almost always associated with long hind legs for making quick dashes to safe retreats, or long limbs for sustained high speed. Jerboas, kangaroo rats, and hares are examples. In cursorial forms, hares for example, the hearing aid that gives superior acoustic sense is usually the large external pinna. In these animals the tympanic bulla, which encloses the middle and inner ear, is small or of medium size. In fossorial forms, for example, jerboas and kangaroo rats, the hearing aid that gives superior acoustic sense is the unusually large tympanic bulla. In these creatures the external pinna of the ear is small or reduced to a mere rudiment. A large or medium-sized pinna (external ear) would be a hindrance in burrowing. The Recent badgers are the most fossorial of all the Carnivora. Therefore, one would expect the pinnae to be rudimentary, as in fact they are. It is known that *Taxidea* "has an ear" for sounds of high pitch. Squeaking sounds made by the writer to attract small birds brought a badger bent on investigating the source thereof. It seems probable that acute hearing assists the badger in locating in the sand or sod such potential food as insects and lizards that burrow there to escape the heat of midday or the chill of evening. A badger seen hunting in late afternoon in Kawich Valley, Nevada, was saved as a specimen. The stomach contents of this individual comprised one lizard, three horned toads, a large camel cricket, and six other kinds of insects. *Taxidea* eats also, probably mainly, small rodents, and locates these more by smell, the writer thinks, than by sound. Even so, acuteness of hearing probably is of real survival value to the Recent *Taxidea,* and because *Pliotaxidea* had relatively larger tympanic bullae, and teeth better developed for masticating insects, it seems reasonable to suppose that its food consisted of insects and other small animals of various kinds. The same reasoning would apply to *Parataxidea.* Until something is known of the appendicular skeleton, it will be impossible to estimate the degree of fossorial adaptation possessed by the Tertiary badgers, but it would be surprising if it were not considerable.

Summary and Conclusions

Badgers of the New World and Old World were generically distinct as far back as approximately the beginning of Pliocene time. In the New World the genera are *Pliotaxidea* of the Tertiary and *Taxidea* of the Quaternary and uppermost Tertiary. In the Old World, the genera are *Parataxidea* of the Tertiary and *Meles* of the Quaternary and perhaps uppermost Tertiary. Two structural features fitting these badgers for their particular way of life are teeth adapted to a mixed diet of insects and small vertebrates, and an auditory apparatus which confers superior acoustic powers. The requisite size and form of molariform teeth and requisite size of tympanic bullae had already been attained in the early Pliocene, although in several other particulars, notably smaller size of the entire animal, less progress had then been registered toward the condition obtaining in Recent badgers.

The close similarity between the Pliocene wolverines, as well as Pliocene ratels, of the Old and New worlds, and the generic dissimilarity of the badgers of that epoch in the two continents, may be accounted for on the basis of latitudinal range. The two groups first mentioned lived in more northerly latitudes than the badgers; the wolverines and ratels were in a favorable geographic position to cross from one continent to the other, and apparently did so, in late Miocene or early Pliocene time, when a land connection existed between Asia and North America in boreal regions. The badgers, on the other hand, may

Comparative measurements (in millimeters) of skull and dentition

	Pliotaxidea				*Taxidea*		
	P. nevadensis, Oregon	*P. nevadensis*, Thousand Creek	*P. nevadensis*, Fish Lake Valley	*P. nevadensis*, Oklahoma	*T. mexicana*, Chihuahua, Mex.	*T. taxus*, Tule Desert, Ariz., ♀, adult, Mus. Vert. Zool. no. 74807	*T. taxus*, Nevada, ♂, adult, Mus. Vert. Zool. no. 24760
Length, anterior end of premaxillae to lambdoidal crest	82.2	....	....	....	....	109.3	124.0
Length, anterior end of premaxillae to posterior side of occipital condyles	69.0*	....	....	....	....	111.9	131.5
Width of rostrum across bone enclosing roots of canines	21.2	....	....	....	....	30.3	37.5
Least width between orbits	18.7*	....	....	....	....	27.2	31.2
Least width behind postorbital processes	15.7	....	....	....	....	28.1	29.6
Width across mastoid processes	54.0*	....	....	....	....	69.1	85.6
Least width between auditory bullae	3.4	....	....	....	....	12.3	13.1
Length of left auditory bulla on axis diagonal to long axis of skull	28.1	....	....	....	....	28.5	35.0
Least width of palate between molars	10.1*	....	....	....	....	17.0	19.5
Length, anterior border of canine to posterior border of M^1	29.3	....	....	....	....	38.5	45.0
Length, anterior border of P^2 to posterior border of M^1	24.0	....	....	....	....	31.4	35.4
P^2, alveolar length	3.6	....	....	....	....	4.0	3.7
P^3, crown length	4.4	....	....	....	....	6.1	7.5
P^3, greatest width	3.2	....	....	....	....	4.5	5.2
P^4, length along outer side	9.0	....	....	....	....	11.1	13.1
P^4, greatest width across protocone	7.3	....	7.9	7.1	....	9.6	10.5
M^1, length along inner side	9.5	....	....	9.9	....	9.7	11.5
M^1, width perpendicular to outer side	8.6	....	....	8.1	....	9.3	9.5
Length, anterior border of P$_4$ to posterior border of M$_2$	18.8	18.0	....	....	....	25.0	27.8
Length, anterior border of P$_2$ to posterior border of M$_2$	26.8	....	....	....	....	36.3	40.3
P$_2$, anteroposterior diameter	3.4	....	....	....	4.2	4.0	4.0
P$_2$, transverse diameter	2.1	....	....	....	2.6	2.7	3.1
P$_3$, anteroposterior diameter	4.5	....	....	....	5.5	5.4	6.1
P$_3$, transverse diameter	2.8	....	....	....	3.2	3.1	3.5
P$_4$, anteroposterior diameter	6.3	6.0	....	....	7.9	7.6	8.6
P$_4$, transverse diameter	3.8	....	....	....	4.4	4.2	4.6
M$_1$, anteroposterior diameter	10.3	9.6	....	10.3	13.0	12.5	14.2
M$_1$, transverse diameter at protoconid	4.8	4.5	....	4.9	6.3	5.2	6.0
M$_1$, anteroposterior diameter of heel	....	3.9	....	4.3	5.0	4.8	5.0
M$_1$, transverse diameter of heel	....	4.5	....	5.0	6.3	5.9	6.5

*Approximate.

then, as they do now, have lived only to the south of this land connection and hence had less opportunity to cross from one continent to the other.

The fossil wolverines and ratels, judging by their dentition, were flesh-eaters. In winter as well as in summer this kind of food is obtainable in the northern (boreal) regions. The fossil badgers, to judge from their dentition, fed on insects and other small animals of varied sorts. In winter, food of this kind is not obtainable in boreal latitudes. The small animals which occur there hibernate or, as in the instance of many insects, live over the winter in an egg stage. Of course the omnivorous bears (subgenus *Euarctos* and presumably subgenus *Ursus*) meet this situation by a long period of winter sleep, and the ground squirrels (*Citellus*), vegetarians, actually hibernate. Although the Recent American badger has the ability to remain inactive below ground for long periods in the northern part of its range in winter, it does not live nearly so far north as do the bears or ground squirrels.

If badgers of the Pliocene were no better able, or, as seems likely, were less able to withstand the vicissitudes of a boreal existence than Recent badgers, their early adaptation to a way of life specialized for a carnivore may have prevented their intercontinental migration. Resulting isolation conceivably hastened differentiation. Perhaps of even greater importance from the standpoint of their phylogenetic development, this isolation prevented competition on one or both continents between the two already differentiated stocks of badgers. If this competition had taken place, *Meles* of the Old World might today inhabit North America as well as Asia, as does the wolverine *Gulo,* and *Taxidea* of the New World might be confined to southern latitudes in America as *Mellivora,* the ratel, is in Asia and Africa.

BIBLIOGRAPHY

Butterworth, E. M. 1916. A new mustelid from the Thousand Creek Pliocene of Nevada. Univ. Calif. Publ., Bull. Dept. Geol., vol. 10, pp. 21–24, 1 fig.

Drescher, A. B. 1939. A new Pliocene badger from Mexico. Bull. Southern Calif. Acad. Sci., vol. 38, pt. 2, pp. 57–62, 1 pl.

Hall, E. R. 1936. Mustelid mammals from the Pleistocene of North America; with systematic notes on some Recent members of the genera Mustela, Taxidea and Mephitis. Carnegie Inst. Wash. Pub. 473, IV, pp. 41–119, 5 pls., 6 figs.

Hesse, C. T. 1936. A Pliocene vertebrate fauna from Optima, Oklahoma. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 24, pp. 57–70, 5 figs.

Martin, H. T. 1928. Two new carnivores from the Pliocene of Kansas. Jour. Mammal., vol. 9, pp. 233–236, 2 pls.

Pilgrim, G. E. 1933. The genera *Trochictis, Enhydrictis,* and *Trocharion,* with remarks on the taxonomy of the Mustelidae. Proc. Zool. Soc. London (1932), pp. 845–867, 2 pls., 2 figs.

Pocock, R. I. 1920*a*. On the external characters of the ratel (*Mellivora*) and the wolverine (*Gulo*). Proc. Zool. Soc. London (1920), pp. 179–187.

——— 1920*b*. On the external and cranial characters of the European badger (*Meles*) and of the American badger (*Taxidea*). Proc. Zool. Soc. London (1920), pp. 423–436, 7 figs.

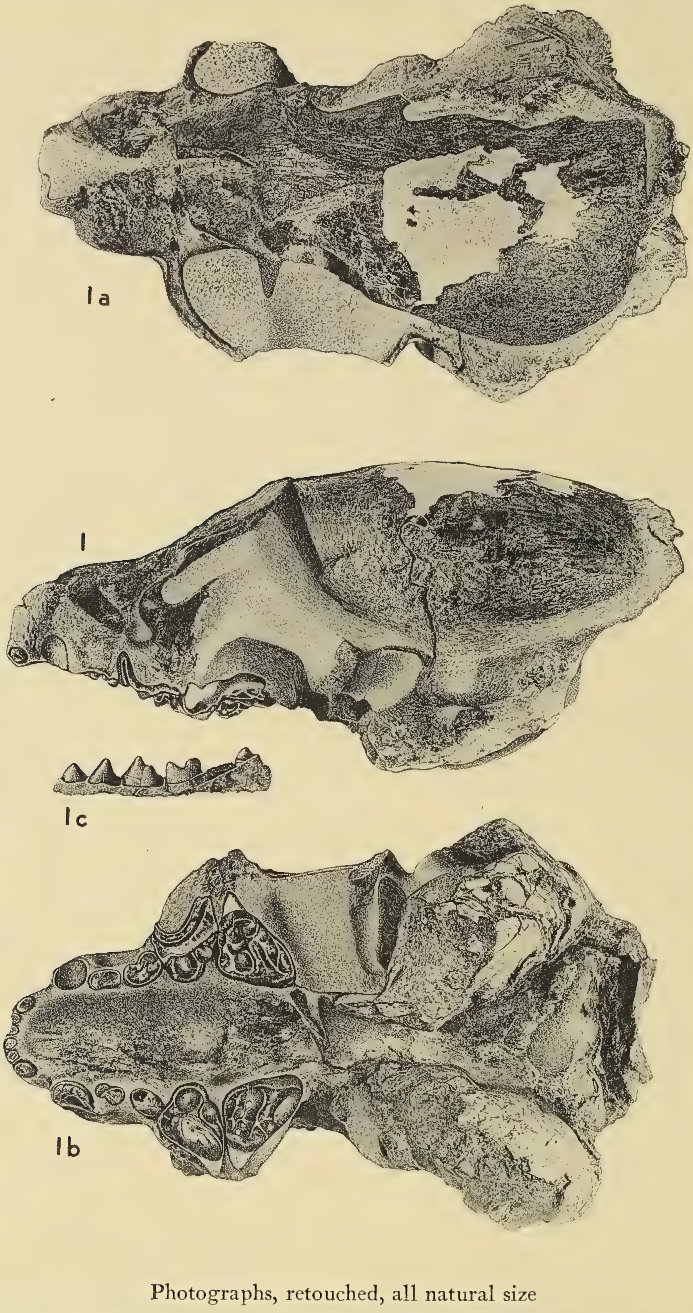
STIRTON, R. A. 1936. Succession of North American continental Pliocene mammalian faunas. Amer. Jour. Sci., ser. 5, vol. 32, pp. 161–206.

STOCK, C., and E. R. HALL. 1933. The Asiatic genus Eomellivora in the Pliocene of California. Jour. Mammal., vol. 14, pp. 63–65, 1 pl.

WILSON, R. W. 1937. Pliocene rodents of western North America. Carnegie Inst. Wash. Pub. 487, II, pp. 21–73, 2 figs.

ZDANSKY, O. 1924. Jungtertiäre Carnivoren Chinas. Palaeontologia Sinica, ser. C, vol. 2, fasc. 1, pp. 1–149, 33 pls., 21 figs.

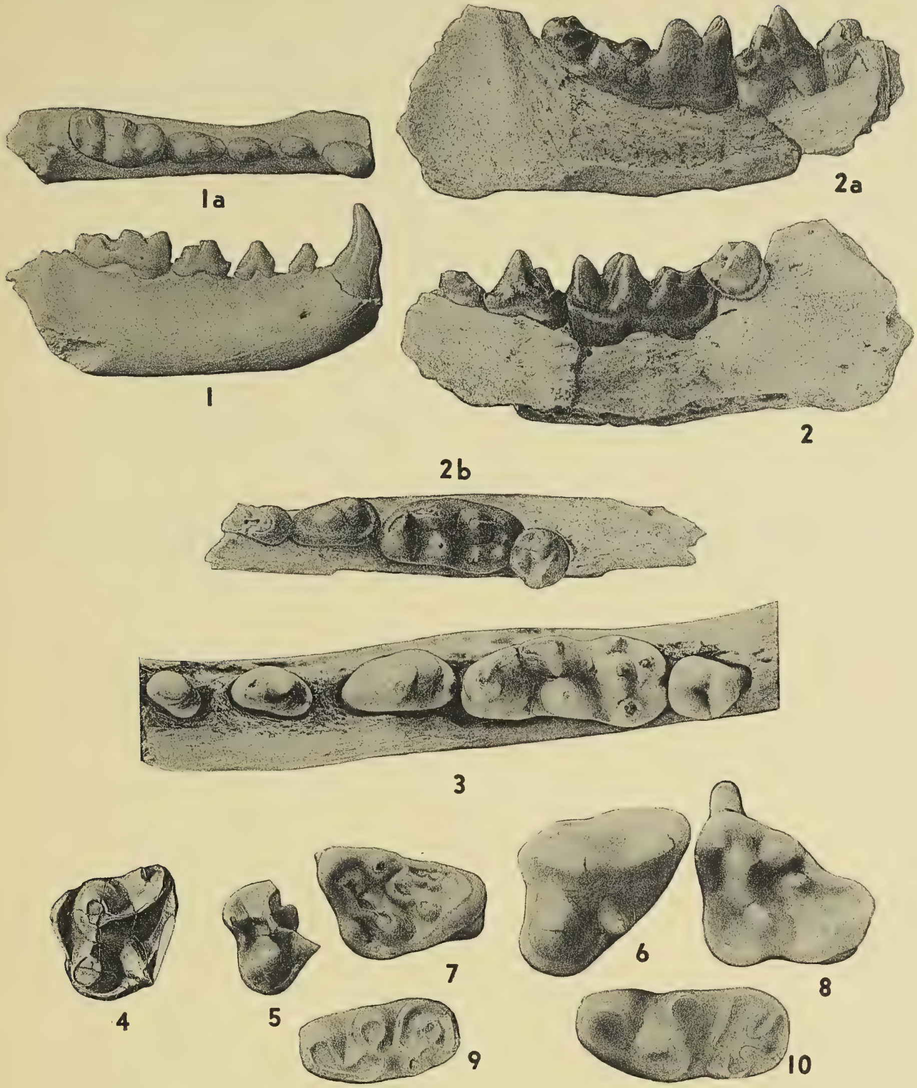
PLATES



Photographs, retouched, all natural size

Skull of *Pliotaxidea nevadensis*, from Stinking Water Creek, Oregon

Fig. 1*a*, dorsal view; fig. 1, lateral view of left side; fig. 1*b*, ventral view; fig. 1*c*, labial view of P2 to M2 inclusive from left lower jaw.



Photographs, retouched: Teeth of American badgers

FIGS. 1, 1*a*. Type specimen of *Taxidea mexicana*, "from C. I. T. Pale. Loc. No. 276 . . . near Rincon, Chihuahua [Mexico], . . . Middle (?) Pliocene." × 1.

FIGS. 2, 2*a*, 2*b*. Type specimen of *Pliotaxidea nevadensis*, from Thousand Creek, Nevada. Fig. 2, lingual view; fig. 2*a*, labial view; fig. 2*b*, occlusal view of right lower jaw. × 2.

FIG. 3. Right lower jaw of Recent *Taxidea taxus*, female, Univ. Calif. Mus. Vert. Zool. no. 11332, from Baker Creek, Modoc County, California. Occlusal view for comparison with type specimen of *Pliotaxidea nevadensis*. × 2.

FIG. 4. *Pliotaxidea nevadensis*, left P^4, from Fish Lake Valley, Esmeralda County, Nevada. × 2.

FIGS. 5, 7, 9. *Pliotaxidea nevadensis*, 3 teeth (see "Referred material" in text), from Texas County, Oklahoma. Fig. 5, P^4; fig. 7, M^1; fig. 9, M1. × 2.

FIGS. 6, 8, 10. *Taxidea taxus*, 3 teeth of Recent badger for comparison with teeth from Oklahoma (figs. 5, 7, 9). Fig. 6 (P^4) and fig. 8 (M^1), female, Univ. Calif. Mus. Vert. Zool. no. 35360, from Palisade, Eureka County, Nevada; fig. 10 (M1), male, Univ. Calif. Mus. Vert. Zool. no. 24641, from Rhyolite, Nye County, Nevada. × 2.

CONTRIBUTIONS TO PALEONTOLOGY

III

Use of Fossil Fish Scales in Micropaleontology

LORE ROSE DAVID

With six plates and nine text figures

[ISSUED JULY 18, 1944]

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Use of Fossil Fish Scales in Micropaleontology

INTRODUCTION

Fossil fish remains are abundantly represented in the marine sedimentary rocks of California. Certain shaly formations are littered with dismembered parts of fish, for example scales and single bones, though few other fossils are found in them. Up to the present time, these fossils have not been utilized in geological and paleontological work in California. An attempt has been made by the author to collect a variety of distinguishable fossils of this kind and to determine to what degree these scale assemblages differ in different stratigraphic units. Approximately 75 distinct types of scale have been found, and the more important ones are illustrated in this paper.

The present report is preliminary in many respects. Only a small number of genera are definitely determined. No names are given to the new forms at present. Instead, the genera are designated by number, the species by letter. It is hoped that the illustrations and identifications will nevertheless be of use to paleontologists.

A general outline for work on fish scales and a description of the technique employed in the study of this kind of material was given by Camp and Hanna (*Methods in Paleontology,* 1937, p. 127). The methods described by these authors can be readily adapted to individual needs.

The investigation on fossil fish scales here reported, conducted during 1941–1942, was supported by several petroleum companies, and it is a pleasure to acknowledge the generosity of these concerns. I wish to thank Dr. Chester Stock for his active interest in the various aspects of the research and for the facilities offered in the paleontological laboratory of the California Institute of Technology. To M. L. Natland, of the Richfield Oil Corporation, I am indebted for the excellent enlarged photographs of fossil scales which he so kindly made and contributed.

DESCRIPTION OF MATERIAL

Occurrence and composition of assemblages. Fossil fish faunas represented by complete skeletons have been found at a number of localities in California, but are restricted almost entirely to the Upper Miocene. Some of these fish faunas are of considerable diversity and give definite information as to conditions of accumulation of the sediments at the place of their occurrence (see David, Geol. Soc. Amer. Spec. Pub. 43, 1943). Scales and dismembered remains of fish are scattered at intervals throughout the entire Tertiary stratigraphic section and are also found in the Upper Cretaceous. Fish remains are present to some degree nearly everywhere, but are often too fragmentary and distorted to be determinable. At intervals richer zones, comparable to the flood zones of the foraminifera, are found, showing a better preservation and a greater variety of forms. Such zones are easily recognized in the field, especially in well cores.

A fish-scale assemblage found fossil cannot be compared with a normal living fish fauna of a given locality. Generally the former shows an abundance of individuals but small variety, and represents a joint occurrence rather than a faunal assemblage of more heterogeneous elements. Fishes that occur abundantly and in large schools in the oceanic realms are likely to leave more frequent records than the rarer forms. It will be seen that certain types are by far the most common in certain sections. Often these types are found to the exclusion of all others, the specific forms changing with the progress of time. These dominant types, because of their more general occurrence, are the most useful for correlation purposes.

Scales of herring-like fishes (Clupeoidea) are extremely abundant in sedimentary accumulations laid down in shallow water, or in the neritic zone and extending into bathyal regions. Silversides (Atherinidae), mackerels (Scombridae), jacks (Carangidae), and, to a certain degree, pipefishes (*Syngnathus*) are also more commonly found in coastal deposits. In regions of deep water, the place of the herrings is taken by a family restricted to abyssal depth, the rattails (Macrouridae). Scales of these fishes are among the best preserved in the California Tertiary.

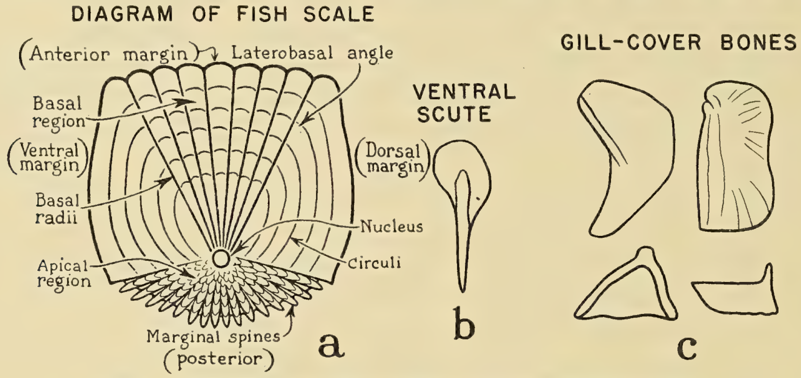


FIG. 1. Diagrams of fish remains most commonly found

Text figure 1*a* illustrates diagrammatically a typical teleostean fish scale, showing the different parts of its sculpture: The basal covered region, where the scale is attached, is most often characterized by strongly folded basal radii; the apical uncovered part of the scale may be with or without marginal spines; the premarginal part of the apical pole may be characterized by radii, a radial network, tubercles, or patterns of differently shaped premarginal teeth. The greater part of the scale is generally sculptured by the circuli, fine lines, most often circular, which take different directions toward the margin of the scale, and are sometimes characterized by a strong laterobasal angle. The center of the circuli is called the nucleus or focus; the apical part of the scale may be free from circuli. Clupeoid scales are marked by strong transverse radii, which are not found so well developed in any other group of fishes.

The scale characters readily permit one to distinguish families and genera. Specific differences can also be determined to a certain extent. The occurrence of fossil types in certain strata, their appearance at intervals interrupted by a lapse of time, favors differentiation into subdivisions of genera and species.

Various single bones of fish are found in the stratigraphic section. Most often these are gill-cover bones. Text figure 1*c* shows the opercular bones of *Etringus,* a round herring, as found in the lower Saucesian; figure 1*b* shows a part of the ventral skeleton of the same form. Various fish jaws are likewise found. Plate 1, figure 2 shows the jaws of a long-toothed abyssal form; figures 1 and 1*a* show head and opercular bones of a pipefish. Fish teeth and ear bones are found in washed samples of foraminifera from certain zones.

SEVERAL TYPICAL SCALE ASSEMBLAGES FROM THE CALIFORNIA TERTIARY

Well cores and surface sections of different formations and of various ages have been studied for fish remains. All locations of oil wells given, unless otherwise indicated, are Mount Diablo base line and meridian.

Eocene A_1, Eocene A_2,—Kreyenhagen Formation

Fish scales are very common in the Kreyenhagen. Only the three most abundant types are figured (pl. 1, figs. 3–5), all from the Seaboard Oil Company Well, Welch No. 1, Sec. 10, T. 16 S., R. 13 E. Two clupeoid forms are most commonly represented in the upper layers of the formation. In the list which follows, the numbers refer to the figures on plate 1.

No. 3. Suborder Clupeoidea. From depth of 4037± feet. Scale 4 mm. long, 5 mm. deep.

No. 4. Family Clupeidae. From depth of 4236 feet. Scale 5.25 mm. long, 6.5 mm. deep.

No. 5. Order Berycomorphi, family Polymixiidae. From depth of 4279± feet. Scale 2.88 mm. long, 2.35 mm. deep. This bathyal genus is extremely abundant in the lower Kreyenhagen, whence the material comes, and is found repeatedly in the section. Basal part of scale very irregularly folded; angular circuli fine and widely spaced, disappearing toward the apical region; marginal spines along apical margin, longest in center.

The same form is found in the Amerada Petroleum Company Well, Beer No. 1, Sec. 17, T. 26 S., R. 19 E., at depth of 4026 feet and still deeper (Eocene A_1). It also occurs in cores of the Texas Company Pioneer Unit Plan Well No. 1, Sec. 33, T. 11 S., R. 23 E., at depth of 8085 feet and still deeper (Eocene A_2).

Refugian

The Refugian stage has been studied from cores of the Amerada Petroleum Company Well, Beer No. 1, Sec. 17, T. 26 S., R. 19 E., west of the Williamson area. The well core is comparatively sandy, however, and the samples available are few. The more characteristic types of a deep bathyal assemblage from the 3500-foot level in this well are shown in plate 1, figures 6–10. They are listed as follows:

No. 6. Family Chaetodontidae?: undescribed genus. From depth of 3540 feet. Elongate acanthopterygian scale, 6.5 mm. long, 4 mm. deep. This type of scale probably ranges higher in the Lower Miocene.

No. 7. Family Halosauridae: undescribed genus. From depth of 3494 feet. Scale 5 mm. long, 3.5 mm. deep.

No. 8. Order Iniomi. From depth of 3513 feet. Scale 1.94 mm. long, 2.59 mm. deep.

No. 9. Family ?. From depth of 3500 feet. Scale 3.25 mm. long, 4 mm. deep. This type of ovoid scale probably ranges downward from the Refugian into the Eocene. Circuli extend entirely around scale; nucleus almost in center of scale; irregular radial radii range all around scale margin.

No. 10. Family Macrouridae: undescribed genus. From depth of 3540 feet. Scale 1 mm. long, 1.5 mm. deep. Spinous apical region makes up greater part of scale.

Zemorrian

A very satisfactory Zemorrian section is found in cores of the Texas Company Pioneer Unit Plan Well No. 1, Sec. 33, T. 11 N., R. 23 W., San Bernardino base line and meridian, in the southern Sunset district, San Joaquin Valley, California.

Upper Zemorrian. Range of *Siphogenerina mayi:* The Upper Zemorrian here shows a deep neritic assemblage, largely dominated by a species of the clupeoid genus *Etringus,* a round herring (pl. 2, figs. 11, 11*a*; text fig. 2). An assemblage not unlike this was found in the Ohio Oil Company "K.C.L.-G." Well No. 1, Sec. 36, T. 29 S., R. 26 E., Fruitvale district, coming near the horizon of a *Siphogenerina* flood zone (*S. transversa, S. mayi,* and *Uvigerinella obesa* are present). The following types are listed, the numbers referring to the figures on plate 2.

No. 11. Family Dussumieridae: *Etringus* sp. "K.C.L.-G." Well No. 1, at depth of 10,434± feet. Scale 5.5 mm. long, 6.5 mm. deep.

No. 11*a*. Family Dussumieridae: *Etringus,* same species. P.U.P. Well No. 1, at depth of 4352 feet. Scale 6 mm. long, 7 mm. deep. This scale is of an older fish than that shown in figure 11, and is slightly distorted; the apical pole is compacted in depth. The scales shown in text figure 2 are from three different wells. The elongate type of scale with the greater number of transverse radii is much rarer than the ovoid type. The number of transverse and apical radii increases with age and size of scale.

Pipefish are not rare in the assemblage (pl. 1, figs. 1, 1*a*) from the P.U.P. well, and are very abundant in well cores from the Fruitvale district:

No. 1. Family Syngnathidae: head of *Syngnathus.* "K.C.L.-G." Well No. 1, at depth of 10,450± feet. 14.5 mm. long, 7 mm. deep.

No. 1*a*. Family Syngnathidae: opercular of *Syngnathus.* P.U.P. Well No. 1, at depth of 4214 feet. 4.5 mm. long, 3.5 mm. deep.

Three species of jack are present in the assemblage, two of which are figured here:

No. 12. Family Carangidae: *Seriola* sp., yellowtail. "K.C.L.-G." Well No. 1, at depth of 10,434 feet. Scale 1.5 mm. long, 0.6 mm. deep.

No. 13. Family Carangidae: *Seriola* sp., yellowtail. "K.C.L.-G." Well No. 1, at depth of 10,434 feet. Diameter of scale 2.5 mm.

A comparatively large scale of a silverside is present:

No. 14. Family Atherinidae. "K.C.L.-G." Well No. 1, at depth of 10,450 feet. Scale 4 mm. long, 4 mm. deep.

No. 14*a*. Family Atherinidae. P.U.P. Well No. 1, at depth of 4344 feet. Scale 3.25 mm. long, 5 mm. deep.

The scales shown in figures 14 and 14*a* evidently belong to the same species.

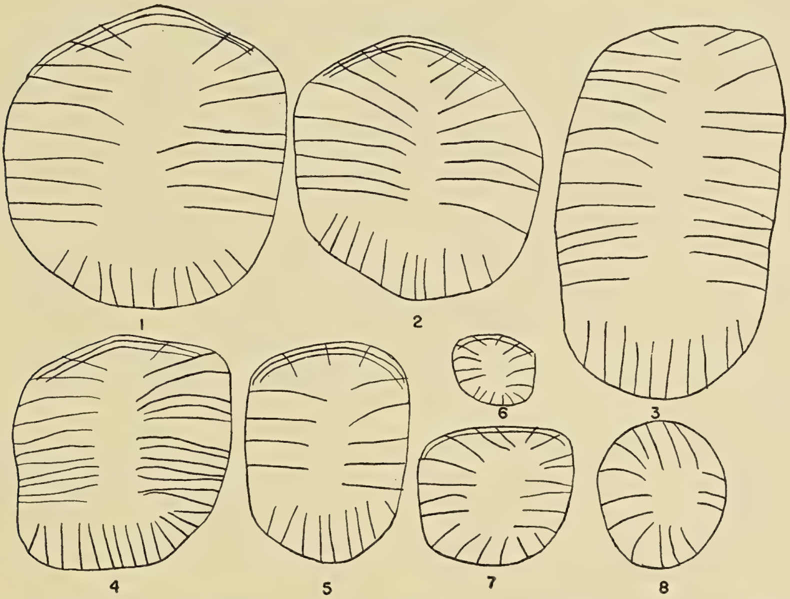


Fig. 2. *Etringus* sp. Specimens from Upper Zemorrian to Lower Saucesian strata. (1) Scale 9 mm. long, 7.7 mm. deep, from Superior Krause Well No. 1, at 12,118 feet depth. (2) Scale 7 mm. long, 6 mm. deep, from Texas Company P.U.P. Well No. 1, at 4387–4395 feet depth. (3) Scale 10 mm. long, 7 mm. deep, from same well, same depth. (4) Scale 6 mm. long, 6 mm. deep, from same well, same depth. (5) Scale of young specimen, 6 mm. long, 4.8 mm. deep, from same well, at 4336 feet depth. (6) Scale of young specimen, 2 mm. long, 2.5 mm. deep, from same well, at 4387-4395 feet depth. (7) Scale of young specimen, 4 mm. long, 5 mm. deep, from same well, at 5280 feet depth. (8) Ventral (?) scale 5 mm. long, 3.75 mm. deep, from Ohio Oil Company "K.C.L.-G." Well No. 1, at 10,430 feet depth.

No. 15. Suborder Salmonoidea. This form seems typical of the Californian stratigraphic section from the Lower Saucesian downward. No related salmon occurs in the California sea today. Scale 15 (pl. 2) comes from the Superior Krause Well No. 1, Fruitvale district, Sec. 2, T. 29 S., R. 26 E., probably from a slightly older horizon (*Siphogenerina nodifera* ?), at depth of 12,118 feet. It was found in a small sample, where the species of *Etringus* was dominant. Scale 5.88 mm. long, 3.94 mm. deep.

Bones from the opercular region of *Etringus* and also a ventral scute (text fig. 1*b, c*) are frequent in the Upper Zemorrian encountered in the P.U.P. well. A greater number of these bones are found in the Fruitvale zone.

Middle Zemorrian. This division comprises the lower part of the range of *Siphogenerina nodifera* and *Uvigenerina belridgensis.* Beginning with the upper Middle Zemorrian, rattails appear in the stratigraphic sequence of the P.U.P. well, indicating presence of a deeper sea. A small form with feeble radii and hardly any spines (pl. 2, fig. 16) appears latest in the section, and is found in the uppermost Middle Zemorrian. In the middle of the Upper Zemorrian, coincidentally with the first appearance of *Uvigenerina belridgensis,* rattails become more abundant, and in the lower Middle Zemorrian rattails are dominant in the section. In large parts of the section nothing but rattails (pl. 2, figs. 16–20) is found; in these zones the sea evidently was more than 1000 fathoms deep. These horizons are interrupted by regions where *Etringus* again becomes somewhat more frequent, but this form is always badly preserved at this depth. The dark shale containing an abundance of rattail is also interrupted several times by a highly sandy shale.

All rattails (Macrouridae) shown (pl. 2) come from the P.U.P. Well No. 1:

No. 16. Family Macrouridae. From depth of 4517± feet. Scale 3 mm. long, 2.5 mm. deep.

No. 17. Family Macrouridae. From depth of 5460 feet. Scale 5.25 mm. long, 4 mm. deep.

No. 18. Family Macrouridae. From depth of 6558 feet. Positive, sculptured side of scale, 4 mm. long, 4.24 mm. deep.

No. 18*a*. Family Macrouridae. From depth of 6228 feet. Mold of sculptured side of scale, 3.12 mm. long, 4.06 mm. deep.

No. 19. Family Macrouridae. From depth of 5688 feet. Mold of sculptured side of scale, 2.94 mm. long, 3.76 mm. deep.

No. 20. Family Macrouridae. From depth of 6558 feet. Smooth side of scale, 2.82 mm. long, 3.12 mm. deep.

Lower Zemorrian. This zone is characterized by the foraminifer *Anomalina californiensis.* The fish assemblage present in the lower Zemorrian of the P.U.P. well is different from that found higher in the section. Rattails disappear almost entirely; nearly all the genera present, however, are bathyal types. The large scale no. 24 (pl. 3) is rather frequent and most typical of the section. This appears to be the upper limit of its occurrence. Herring scales are present, but nearly always distorted, and it seems likely but not certain that a species change has taken place. All scales listed below are from the P.U.P. Well No. 1:

No. 21. Family Thunnidae: possibly *Thunnus.* From depth of 7600 feet. Scale 3.23 mm. long, 3.6 mm. deep.

No. 22. Order Iniomi: undescribed genus. From depth of 6622 feet. Scale 4 mm. long, 4.5 mm. deep.

No. 23. Family Halosauridae: *Laytonia* sp. From depth of 7304 feet. Scale 3.82 mm. long, 3.52 mm. deep. A scale nearly related to this one was described by T. D. A. Cockerell (U. S. Geol. Surv. Prof. Paper 120, p. 184, 1919).

No. 24. Order Berycomorphi, family ?. From depth of 7400 feet. Scale 7.5 mm. long, 7.7 mm. deep.

These Zemorrian assemblages are highly interesting, even though they come almost entirely from one well. The stratigraphic section shows very distinctly a subdivision into three parts. The distinctness of the lowermost assemblage indicates that a general faunal change occurred between that period and those that follow, causing extinction of certain types. The change occurring between the upper and middle parts of the section is explained entirely by facies differences.

Saucesian

The lower Saucesian is marked in thick sections by a great abundance of opercular bones belonging to *Etringus*. This fact has already been reported for the Lower Saucesian to Upper Zemorrian in the Ohio Oil Company "K.C.L.-G." Well No. 1, and is found to hold also for the cores of the P.U.P. well sampling strata overlying the Upper Zemorrian. The same fact can be recorded for the Saucesian of the Associated Williamson Well No. 1, Sec. 2, T. 26 S., R. 20 E., Williamson area, at a depth of approximately 6600 feet and lower. Several small samples from the Etienne Lang "Occidental" Well No. 2, Sec. 30, T. 26 S., R. 19 E., west of the Lost Hills area, from the Santos shale showed the same forms, as well as samples from the Harold C. Morton Well No. 1 analogue Etienne Lang "Occidental" No. 2, in the same region. These bones occur frequently again in the Saucesian of the Texas Company Well, Newman No. 1, Sec. 23, T. 29 S., R. 28 E., on the southeastern border of the San Joaquin Valley, at a depth of approximately 5800 feet and lower. The accompanying scales of *Etringus* found in these sections are small compared with those found in the Upper Zemorrian, a difference which may be explained by local conditions. A great many fragments of fish bones were observed in washed samples from the Saucesian and Upper Zemorrian of Los Sauces Creek. One or two different clupeoid forms evidently occur in the Upper Saucesian, but sufficient material has not been seen. A more continuous Saucesian section has been studied in the Texas Company Well, Newman No. 1 (pl. 3), Kern River district, Sec. 23, T. 29 S., R. 28 E. Not much material is available, however, and the well is quite sandy. A number of coastal shallow-water forms of fish are present in the Upper Saucesian, mostly too fragmentary for exact determination.

No. 25. Family Clupeidae: a clupeid form, probably a young shad. From depth of 3748 feet. Length of scale 4.71 mm., depth 5.76 mm.

Macrouridae are present in the lower part of the well, but are not dominant. A small scale of a rattail is present in higher horizons:

No. 26. Family Macrouridae. From depth of 5423 feet. Length of scale 2.41 mm., depth 2.65 mm.

No. 27. Family Macrouridae: a quite different species of rattail. From depth of 5741 feet. Length of scale 2.94 mm. with spines, depth 2.94 mm.

Other species of rattail appear farther down in the well. Finally there appears also occasionally no. 18, shown for the Zemorrian.

Relizian and Luisian

Both stages are represented in the Newman Well No. 1, but the material is not very satisfactory. The clupeid form no. 25 is present in both stages.

A typical round herring is characteristic of the Relizian:

No. 28. Family Dussumieridae. From depth of 3639 feet. Length of scale 4 mm., depth 5.29 mm.

The assemblage is near-shore neritic, the more common types beings jacks and smelts, with a few acanthopterygians also present. The Luisian seems to be characterized by porgy fishes, for example *Rhythmias* and *Plectrites* (not figured).

Mohnian

The greatest variety of scales is found in the Mohnian. This is also the stage from which come the majority of the more completely assembled fish skeletons. The Mohnian assemblages are in general neritic, with types indicating local deepening of the sea. The Mohnian has been studied from outcrops in the Santa Monica Mountains. Localities in the eastern part of the mountains are for the most part near Sepulveda Canyon (for descriptions of localities see David, Geol. Soc. Amer. Spec. Pub. 43, 1943). Fossil sites in the type region of the Mohnian (Girard-Mohnsprings, now called Girard–Mineral Springs) are the same as Hoots' foraminiferal localities (U. S. Geol. Surv. Prof. Paper 165C, 1931). Our knowledge of these sections is still incomplete, and more collecting, with detailed stratigraphic studies, is desirable. Several small samples from the Western Gulf Oil Company Symons Well No. 12-17, Sec. 7, T. 32 S., R. 27 E., Buena Vista district, San Joaquin Valley, furnished Upper Mohnian material from below the Stevens zone. The Western Gulf Oil Company Lechler Well No. 1 from Oakridge also furnished some scattered Upper Mohnian scales. Lower Mohnian was found in the Findley Frazier "Portals" Well No. 1, Sec. 4, T. 30 S., R. 29 E., Edison district.

Mohnian clupeoid fishes. Some remarks regarding the occurrence and use of this type of scale seem desirable here. Scales of herring-like fishes are well differentiated from those of all other groups. They are characterized by well marked, variously directed transverse radii on the basal part, generally paired, the lowermost pair united more often to form a complete ridge separating the apical part from the remaining part of the scale. The circuli are always very fine and cover the basal part; to the left and right of the center they extend onto the apical part, where they widen somewhat; they are slightly curved in the dorsoventral direction. The apical part is of simplified structure, divided only by apical radii differing in number. Scales differ more strikingly on the same fish in the herrings than in some of the other groups (Storey, Stanford Ichthyol. Bull., vol. 11, pp. 21, 22, 1938). However, the majority of scales from each fish, that is all the lateral scales, are similar. Scales toward the dorsal and ventral extremities of the body are aberrant. The aberrant scales may show transitions between different types and are often hard to distinguish. It is therefore advisable not to attempt determination on the basis of a single scale, but to consider a number of scales showing the variety present in a given horizon. As has been stated, herrings are always present in greater abundance than other fishes.

Four genera of herring-like fishes (see text figs. 3–6) are found in different parts of the Mohnian section. Typical specimens of the different forms are shown on plate 3, figures 29, 30, and plate 4, figures 31, 32. The drawings (text figs. 3–6) show the variations in scales of each type.

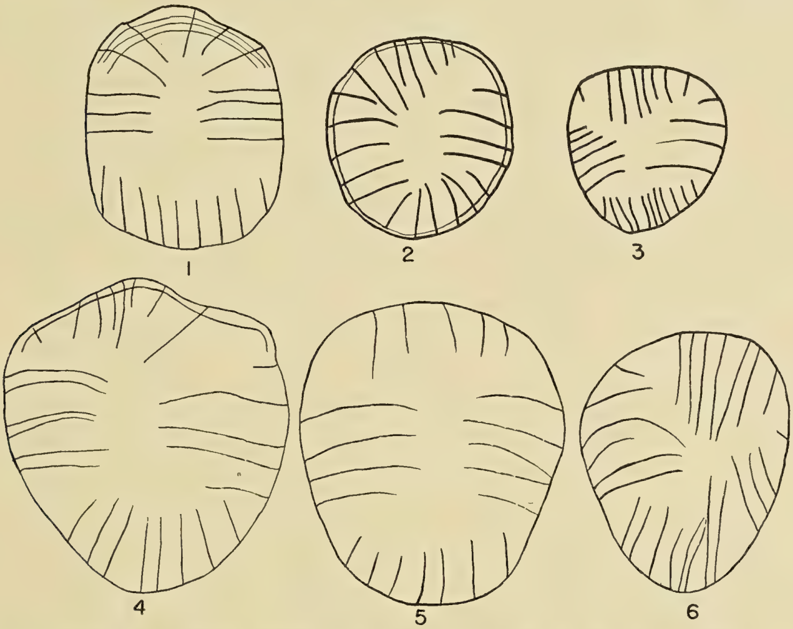


Fig. 3. Undescribed clupeoid genus. Specimens from the base of the Mohnian. (1) Scale 7 mm. long, 6 mm. deep, from Findley Frazier "Portals" Well No. 1, at 3680–3685 feet depth. (2) Scale 6 mm. long, 5.5 mm. deep, from same well, at 3651–3670± feet depth. (3) Scale 5.25 mm. long, 5 mm. deep, from same well, at 3670–3674± feet depth. (4) Scale 9 mm. long, 8.5 mm. deep, from Altamira shale at top of Palos Verdes Hills. (5) Scale 6.2 mm. long, 5.25 mm. deep, from same locality. (6) Ventral (?) scale 8 mm. long, 6.25 mm. deep, from Findley Frazier "Portals" Well No. 1, at 3680–3685± feet depth.

No. 31. Family Dussumieridae: ?*Etringus* sp., from the base of the Mohnian (text fig. 3). The scale occurs in the Altamira shale of the Palos Verdes Hills. The same scale has been found in the Findley Frazier "Portals" Well No. 1, in the *Pulvinulinella gyroidinaformis* zone, probably in the lower third of this zone. The form is characterized by transverse radii running in various directions; the number of parallel paired transverse radii, if present, is smaller than in the following form. This specimen comes from Findley Frazier "Portals" Well No. 1, at depth of 3660 feet. Length 5.5 mm., depth 5.47 mm.

No. 32. Family Dussumieridae: *Etringus scintillans* (text fig. 4), a round herring extremely abundant in the Lower Modelo of the Santa Monica Mountains. It was found in the Sepulveda Canyon region at localities corresponding to Hoots' unit 7 or 7 to 8, extending to and including the lower half of 9 (*Bolivina hughsi* zone) of

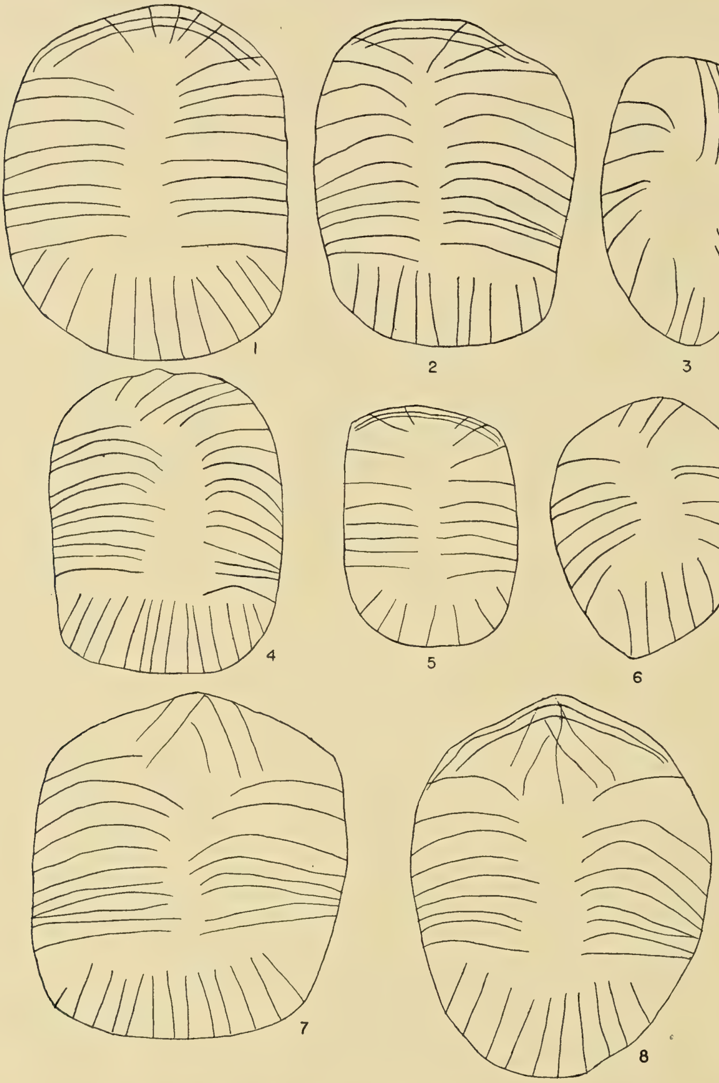


Fig. 4. *Etringus scintillans.* Specimens from Lower to Middle Mohnian strata. (1) Scale 11.75 mm. long, 9 mm. deep, from Sepulveda Canyon, Santa Monica Mountains, C.I.T. locality 334. (2) Scale 11 mm. long, 8 mm. deep, from Axis Company Rowland Well No. 1, at 2105–2127 feet depth. (3) Ventral (?) scale 9.5 mm. long, 5.5 mm. deep, from same locality as (1). (4) Scale 13 mm. long, 10 mm. deep, from Girard–Mineral Springs, Santa Monica Mountains, near Hoots' locality 117. (5) Scale of young specimen, 7 mm. long, 6.2 mm. deep, from same locality as (1). (6) Dorsal (?) scale 8 mm. long, 6 mm. deep, from same locality. (7) Scale 10 mm. long, 10 mm. deep, from Kraemer shale, Puente Hills. (8) Scale 11 mm. long, 10 mm. deep, from Lower Mohnian, Puente Hills.

the type locality. In the Girard–Mineral Springs section, an abundance of scales of this form occurs between Hoots' localities 117 and 118 (no scales have yet been collected at localities 119 to 130). *Etringus* is characterized by numerous paired transverse radii and widely spaced radii in the apical region. *Etringus scintillans* differs from the species found in the Saucesian-Zemorrian section (pl. 1, figs. 11, 11*a*) in its more elongate shape. The apical radii are longer and less numerous as compared with the number of paired transverse radii. The direction and shape of the uppermost radii are less symmetrical in the Upper Miocene species. The number of radii increases with age, as has been said before. The scales on the caudal peduncle show a greater number of transverse radii. Specimen from the Lower Modelo, Sepulveda Canyon, C.I.T. locality 317. Length 7.9 mm., depth 7.9 mm.

No. 29*a, b*. Family Clupeidae: *Xyne grex* (text fig. 5), evidently a true herring. This form was described first from the Celite quarries of Lompoc, Santa Barbara County, which are of Delmontian age, corresponding to unit 18 of the Modelo type locality (information supplied by Dr. M. N. Bramlette). *Xyne* is found in the Sepulveda Canyon region of the Santa Monica Mountains in the upper half of unit 9 (*Bolivina hughsi* zone). It is abundant here and seems to take the place of *Etringus*, which is not found so high as this horizon. In the Girard–Mineral Springs section *Xyne* is found abundantly at Hoots' localities 133 to 136 (corresponding to the horizon where *Xyne* is found in the eastern part of the mountains). Furthermore, *Xyne*, or a related form, is present in the Western Gulf Symons Well No. 12-17, a few hundred feet below the top of the Stevens zone. Here also the opercular bones of this form occur. The fish was found also in the Monterey hills in the vicinity of South Pasadena, and at other localities in southern California. In the scale of *Xyne* the apical part is separated from the basal part by a complete transverse line; fewer transversely paired radii are present, and these are otherwise directed than in *Etringus*. Specimens from Western Gulf Symons Well No. 12-17, at depth of 11,595–11,596 feet. Dimensions: (*a*) length 4.88 mm., depth 5.88 mm.; (*b*) length 4.59 mm., depth 4.88 mm.

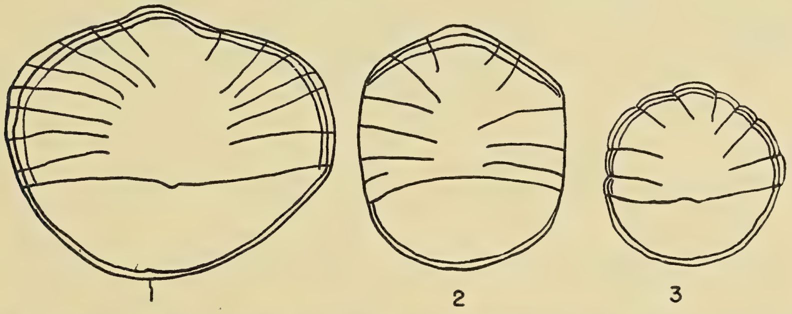


Fig. 5. *Xyne grex*. Specimens from Upper Mohnian strata. (1) Scale 8 mm. long, 9.5 mm. deep, from Girard–Mineral Springs, Santa Monica Mountains, near Hoots' locality 134. (2) Scale 7.25 mm. long, 6 mm. deep, from same locality. (3) Scale 4.2 mm. long, 4.1 mm. deep, from same locality.

No. 30. Two large species of shad, *Ganolytes cameo* and *Ganolytes aratus*, occur in Mohnian sections. *Ganolytes cameo* (pl. 3, fig. 32; text fig. 6, nos. 1, 2,.5), the older species, is much heavier and deeper. It has been described from the Lower Modelo and is very abundant there, accompanying *Etringus scintillans* in the

Sepulveda Canyon section as well as at Hoots' localities 117 and 118, Girard–Mineral Springs. *Ganolytes aratus,* described from Lompoc, is probably represented by scales and other fragments in the Upper Mohnian. The ranges of these species of *Ganolytes* may overlap in the Middle Mohnian. The two species have been described and distinguished after complete skeletons found in Upper Miocene deposits. It has not been possible so far to define the differences between their scales. The large scales of the shads are easily recognized: A varying number of irregular transverse radii are present; the ends of the radii are often marked by a row of small round depressions; these depressions generally occur in the center of the scales, especially in larger specimens. The radii are strongest in *G. cameo.* The apical region is separated by a complete ridge and divided by numerous apical radii which may show small round depressions. Specimen of *Ganolytes cameo,* from Topanga Canyon, Modelo formation. Length 15.7 mm., depth 17.3 mm.

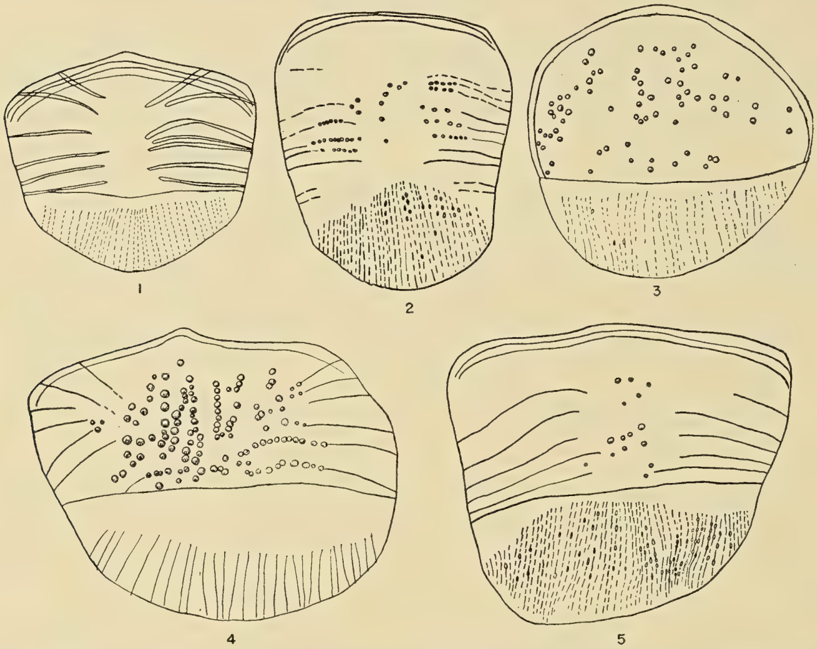


Fig. 6. *Ganolytes* sp. Specimens from Lower to Middle Mohnian strata. (1) *G. cameo,* scale 11 mm. long, 12 mm. deep, from Sepulveda Canyon, Santa Monica Mountains, C.I.T. locality 317. (2) *G. cameo,* scale from caudal peduncle (?), 12 mm. long, 10 mm. deep, from Girard–Mineral Springs, Santa Monica Mountains, near Hoots' locality 116. (3) *Ganolytes* sp., scale 10 mm. long, 10 mm. deep, from same locality. (4) *G.* cf. *aratus* ?, scale 11.2 mm. long, 13.2 mm. deep, from Sepulveda Canyon, Santa Monica Mountains, C.I.T. locality 334. (5) *G. cameo,* scale 15.2 mm. long, 16.5 mm. deep, from Lower Modelo, Topanga Canyon, Santa Monica Mountains.

It is fortunate that there is an abundance of different types of herring-like fish in the horizons of the Upper Miocene, and it is hoped that these forms can be used in correlating different stratigraphic sections. It is likely that the so-called thread herring, *Opisthonema* from the Altamira shale (see David, Geol. Soc. Amer. Spec. Pub. 43, p. 84, 1943) dies out after the Middle Miocene. *Etringus* is restricted to the Mohnian stage in the Los Angeles Basin. Both evidently are warm-water types. *Xyne* and the shads range up into at least the Delmontian, but nothing like these forms exists in the North Pacific Ocean today. The shad living now in Pacific waters is a very different fish, and was introduced from the East by the U. S. Fish Commission. The shads appear first in the California Tertiary section during the Upper Saucesian stage. A species of *Ganolytes* is found more often in the Middle Miocene (see pl. 3, no. 25). True abundances of the large scales of the genus have been noticed only beginning with the Mohnian stage. It remains to be seen whether the faunal change indicated by the substitution of *Xyne* for *Etringus* in the Upper Mohnian of the Santa Monica Mountains is a general one. To make better use of these forms, it is necessary to institute a more detailed study of the species and especially to investigate the development of the scales from young fishes to adults. The age of a fish is shown on the scale by the annual rings. It is possible that young shad scales resemble those of *Xyne* to some degree. *Etringus scintillans* as a genus is well differentiated from other Mohnian forms. A different species of *Etringus* is found in the Lower Miocene (see above).

Lower Mohnian. The more common forms are chosen from a variety of scales found in the Lower Mohnian (pl. 4). Many of these extend up into the Upper Mohnian and Delmontian.

No. 33. Family Atherinidae: *Zanteclites* sp. *Zanteclites hubbsi* was described from the Lower Mohnian. The type having been lost, however, it is not certain that the scale belongs to this form. The scale illustrated is from Sepulveda Canyon, Lower Modelo, C.I.T. locality 317. Length 4.25 mm., depth 3.5 mm.

No. 34. Family Scombridae: *Pneumatophorus* cf. *grex.* The common mackerel from the California Upper Miocene was assigned to the Recent Atlantic species. The scale conforms with the latter. Continental Oil Company "Turnbull" No. 3, Puente Hills, at 4575 feet depth, Lower Puente. Length 3.5 mm., depth 4.1 mm. Circuli transverse, those of basal region more widely spaced. Adjacent basal and apical circuli in center almost parallel (compare with the related scales of *Sarda*). Apical radii and irregular folding present along apical margin.

No. 35. Family Thunnidae: *Sarda* cf. *stockii,* a bonito. Union Oil Company "Chapman" No. 29, at 7842–7850 feet depth, Lower Puente. Length 3 mm., depth 4.8 mm. Circuli of basal region irregularly angled and curved; in other scales (see following number) circuli become almost circular concentric.

No. 36. Same, same well at 4440–4449 feet depth, Kraemer sand (= Upper Mohnian). Length 2.5 mm., depth 4 mm.

No. 37. Family Carangidae: *Decapterus* (*Lompochites*) cf. *hopkinsi,* a jack. Continental Oil Company "Turnbull" No. 3, at 4320 feet depth. Length 3.3 mm., depth 3 mm.

No. 38. Family Carangidae: probably *Decapterus* sp. C.I.T. locality 317, Sepulveda Canyon. Length 2.06 mm., depth 1.76 mm.

No. 39. Family Sciaenidae: *Lompoquia* sp.? Girard–Mineral Springs, near Hoots' locality 117. Length 3.65 mm., depth 2.82 mm.

No. 40. Family Sciaenidae: *Lompoquia* cf. *culveri.* Girard–Mineral Springs, near Hoots' locality 117. Length 3 mm., depth 3 mm.

No. 41. Family Scorpaenidae: *Sebastodes* sp., a rock cod. C.I.T. locality 317, uppermost strata, Sepulveda Canyon. Length 5.4 mm., depth 5.4 mm.

No. 42. Family Scorpaenidae?. Girard–Mineral Springs, near Hoots' locality 117. Length 4.41 mm., depth 3.12 mm.

Middle to Upper Mohnian. The more common species in these zones were again chosen from the large variety of forms present (pl. 5). Jacks are very abundant (text figs. 7, 8). A species related to the living scad, family Carangidae: *Decapterus* (*Lompochites*) cf. *hopkinsi* (see text fig. 7), is the most common jack found at Hoots' locality 134, Girard–Mineral Springs. Scale hexagonal to rounded. Nucleus basad of center of scale; central circuli rounded to ovoid, dense, of small diameter; hardly angular; angles irregularly formed near outer borders of basal part of scale.

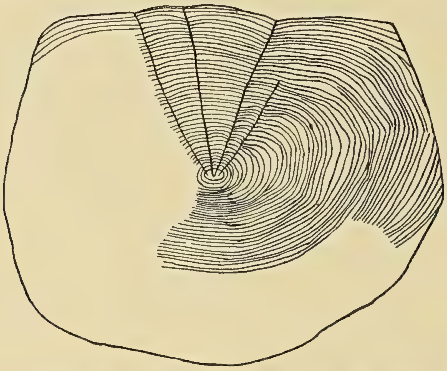


Fig. 7. *Decapterus* cf. *hopkinsi*. Scale 3 mm. long, 3.5 mm. deep, from near Hoots' locality 136.

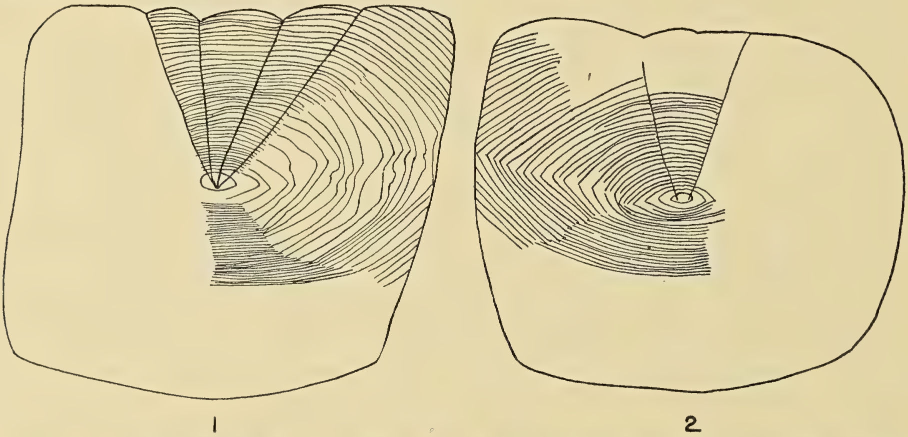


Fig. 8. Undescribed genus. (1) Scale 3.1 mm. long, 3.9 mm. deep, from Hoots' locality 134. (2) Scale 3 mm. long, 3.2 mm. deep, from Axis Company Rowland Well No. 1, at 2367–2384 feet depth.

No. 43. Family Thunnidae: *Sarda* cf. *stockii*. Girard–Mineral Springs, Hoots' locality 134. Length 2.82 mm., depth 2.94 mm.

No. 44. Family Zaphlegidae: *Zaphleges* cf. *longurio.* Western Gulf Symons No. 12-17, at 11,595–11,596 feet depth. Length 2.71 mm., depth 2.94 mm. Scale rounded to oval, folded concentrically to basal part of scale. Nucleus apicad to center. Circuli symmetrically angular in apical part of scale.

No. 45. Family Pomatomidae: *Pseudoseriola* sp. Western Gulf Symons Well No. 12-17, at 11,595–11,596 feet depth. Length 3.06 mm., depth 4.88 mm. Scale quadrangular, folded concentrically to basal border. Central circuli symmetrically rectangular, their basal border rounded, apical border straight.

No. 46. Same? Same well, same depth. Length 3.82 mm., depth 2.35 mm.

No. 47. Family Thunnidae: *Sarda* cf. *stockii.* Girard–Mineral Springs, near Hoots' locality 136. Length 2.59 mm., depth 1.94 mm.

Nos. 48, 48*a*. Family Atherinidae: undescribed genus and species related to the bay smelt of California. Circuli of mid-lateral scales little extended beyond laterobasal angle; strong apical spines; laterobasal angle of lateral scales strongly acute, with circuli showing concave curvature before meeting in angle. No. 48, Girard–Mineral Springs, Hoots' locality 134; length 2.25 mm., depth 3.25 mm. No. 48*a,* Western Gulf Symons Well No. 12-17, at depth of 11,595–11,596 feet; length 2.24 mm., depth 2.65 mm.

Nos. 49, 49*a*. Family Atherinidae: undescribed genus and species. Mid-lateral scales very much deepened; laterobasal angle acute but circuli almost straight. Girard–Mineral Springs, Hoots' locality 136. No. 49, length 1.37 mm., depth 4.00 mm. No. 49*a,* length 2.12 mm., depth 2.47 mm.

No. 50. Family Sparidae: *Rhythmias* sp. Scales with strong basal folds, circuli directed toward dorsal and ventral margin, generally no marginal spines. Western Gulf Symons Well No. 12-17, at depth of 11,595–11,596 feet. Length 2.19 mm., depth 3.53 mm.

Nos. 51, 51*a*. Family Sciaenidae: *Lompoquia* cf. *culveri.* Girard–Mineral Springs, Hoots' locality 134. No. 51, length 3.17 mm., depth 3.46 mm. No. 51*a,* length 4.06 mm., depth 3.71 mm.

No. 52. Undetermined. Girard–Mineral Springs, Hoots' locality 134. Length 6.29 mm., depth 8.23 mm.

No. 53. Family Sciaenidae: *Lompoquia* sp. Girard–Mineral Springs, Hoots' locality 134. Length 3.06 mm., depth 2.65 mm.

A small lantern fish is found abundantly represented in the uppermost Mohnian of the Los Angeles Basin. The entire fish is found rather than its scales, indicating deep neritic to bathyal surroundings of deposition. This fish and *Bathylagus,* another bathyal form, were found along the northern rim of the Santa Monica Mountains at C.I.T. localities 326, 329, and 379 in the region of Sepulveda Canyon, and at Hoots' localities 136 and 142 of the Girard–Mineral Springs section.

Delmontian and Pliocene

No material has been studied from the Delmontian. P. P. Goudkoff's fish-scale zone lies in this stage (see Bull. Geol. Soc. Amer., vol. 50, p. 1950, 1939). The fossil fish fauna from Lompoc, the richest known from the Pacific coast area, is of Delmontian age.

Pliocene deposits have not been studied. Good scales occur in the Repetto formation of southern California. In general the lithology of the Pliocene is such as to appear unfavorable to the preservation of scales, but fish vertebrae are encountered from time to time.

Summary of Known Tertiary Silversides

The scales of the silversides, family Atherinidae, with their very distinct laterobasal angle and the deepened mid-lateral scales, are easily distinguished from those of all other groups. They are also sufficiently abundant to be of use in correlation. Four species, possibly five, found in different California Tertiary sections, are compared on plate 6. Another is shown in text figure 9.

Form 1 (figs. 1, 1*a*), from the Upper Zemorrian. Same as nos. 14, 14*a*, plate 2.

Form 2 (fig. 2), from the Lower Mohnian and probably Relizian, *Zanteclites* ?. Same as no. 33, plate 4.

Form 3 (figs. 3, 3*a*, 3*b*), from the Upper Mohnian, San Joaquin Valley, Western Gulf Symons Well No. 12-17, at depth of 11,595–11,596 feet. Fig. 3, scale 1.2 mm. long, 2.8 mm. deep; fig. 3*a*, same as no. 48*a*, plate 5; fig. 3*b*, scale 2 mm. long, 1.7 mm. deep.

Form 4 (figs. 4, 4*a*), from the Upper Mohnian, Girard–Mineral Springs, Hoots' locality 134. Fig. 4, 2 specimens, upper partly superimposed on lower, upper same as no. 48, plate 5; fig. 4*b*, scale 2.1 mm. long, 2.2 mm. deep.

Form 5 (figs. 5, 5*a*), from the Upper Mohnian, Girard–Mineral Springs. Same as nos. 49, 49*a*, plate 5.

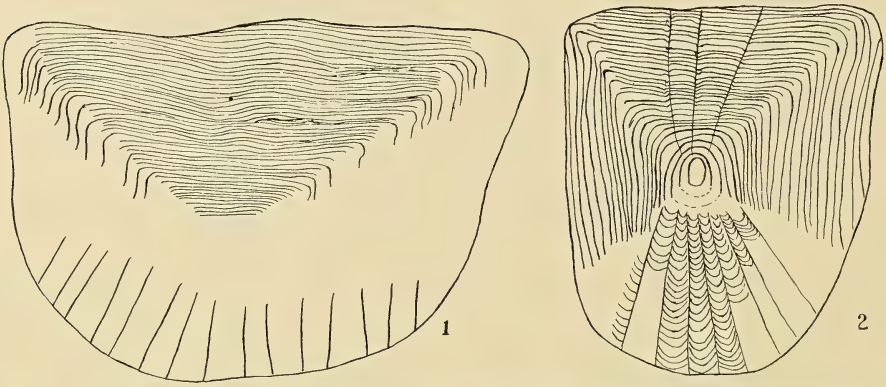


Fig. 9. *Zanteclites* sp. Specimens from McLure shale, San Joaquin Valley, Ohio Oil Company "Bear State" Well No. 23. (1) Scale 4 mm. long, 5 mm. deep, from 4636 feet depth; × 12. (2) Scale 3.1 mm. long, 2.8 mm. deep, from 4477 feet depth; × 14.

Form 6 (text fig. 9), from the Upper Mohnian, *Bolivina brevior* zone. Ohio Oil Company "Bear State" Well No. 23, Sec. 30, T. 28 S., R. 21 E. This is the largest silversides scale found so far; it is characteristic for the McLure shale of the San Joaquin Valley. Circuli always denser in central sector of basal part of scale. In the deep lateral scales circuli may or may not be present in dorso- and ventrobasal sectors; if present they are irregular and more or less shortened.

Conclusions

Determinable fossil fish remains in California are undoubtedly abundant and of considerable variety as to type. The foregoing report shows that well characterized remains are readily available and can be expected in all parts of the Tertiary section. Hard, shaly diatomaceous deposits are the most favorable for fish-scale preservation, and in shale units of certain formations scales are the most readily available fossils for correlation.

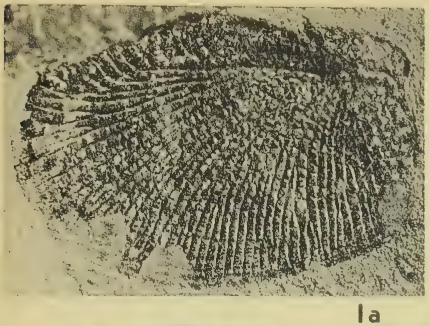
Fish scales have sufficient characterization and are large enough to be used in the field. At certain horizons in the stratigraphic sequence an abundance of specific types of scale is present; where they occur in any number they cannot be overlooked, and can be recognized with a small magnifying glass.

As in the instance of fossil foraminifera, particular kinds of scale distinguish certain parts of the geologic column. The differences noted are due in part to facies changes, and in part to more general faunal changes that have taken place with the lapse of time. Fossil fishes furnish evidence by which the ecological conditions during deposition of marine rocks can be definitely determined. Most fishes are restricted to certain environments as regards temperature and depth, and are therefore unlike many foraminifera, which can live just as well in cold as in deep water. Fish-scale assemblages can be readily identified as to their abyssal, bathyal, neritic, or littoral character. When the assemblages become better known, evaluation of the different factors involved will give even more definitive information as to ecological conditions. In this respect the scales supply a satisfactory check on the zoning established through use of the foraminifera, and aid in a better recognition of the size and extent of ancient sea basins.

Utilization of fossil fish scales permits the division of geologic time into units probably somewhat larger than stages. Scales are of special use in horizons where a definite faunal change has occurred. Such changes do not seem to coincide with the divisions that have been established by use of the foraminifera. The number of different types of fish remains is not extremely great. The best results in solving problems of correlation of strata can doubtless be obtained when fossil fish scales are utilized along with foraminifera. The degree of abundance of different kinds of fish should likewise furnish reliable information, once these forms have been identified.

Valuable data relating to problems of sedimentation and oceanography can be obtained from a study of the type of material discussed in this paper. Presence or absence of fresh-water outlets and strength and direction of oceanic currents along the border of the marine basin are indicated by the composition of the scale assemblages.

PLATES



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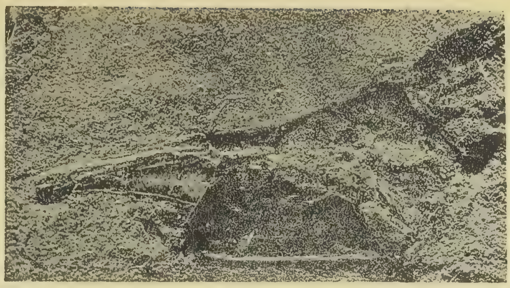

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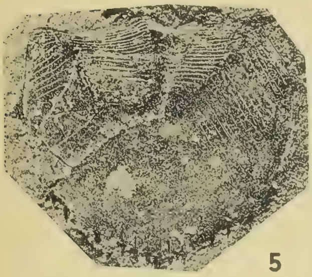

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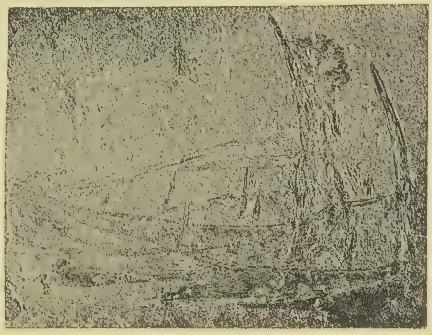

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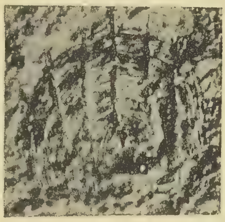

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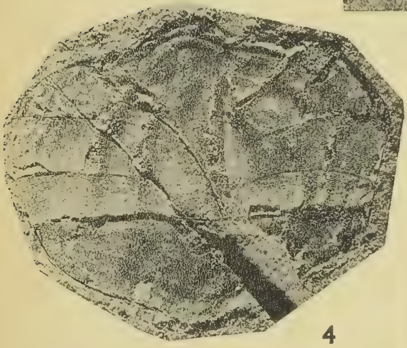

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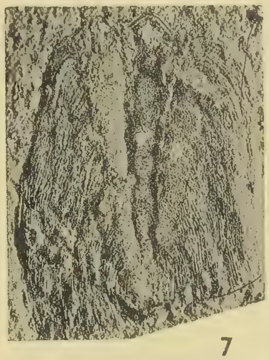

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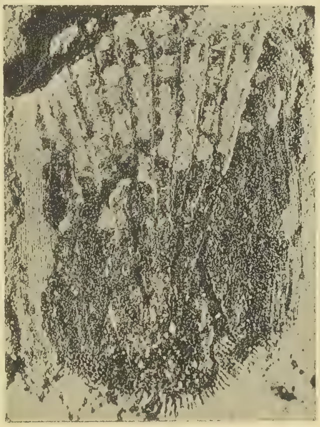

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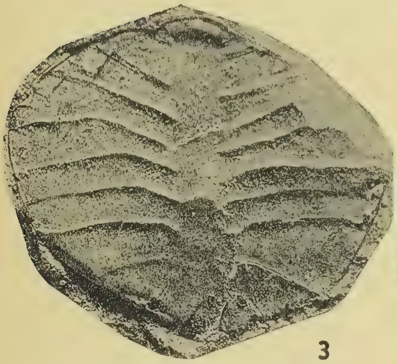

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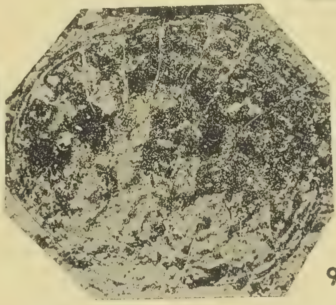

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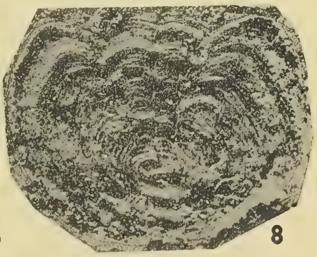

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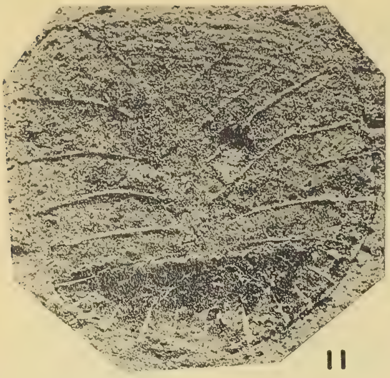
UPPER EOCENE AND LOWER MIOCENE FISH REMAINS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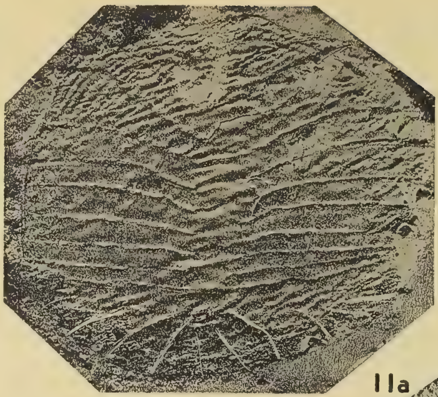
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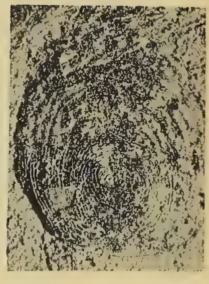
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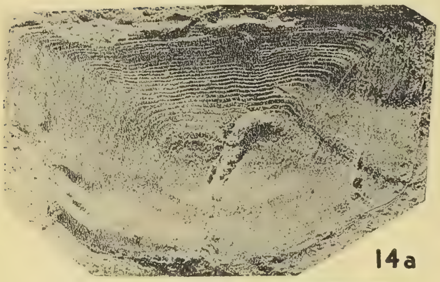
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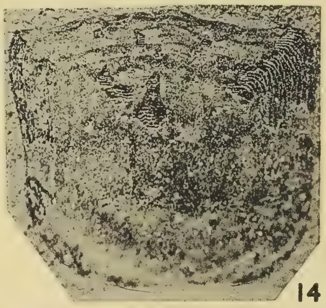
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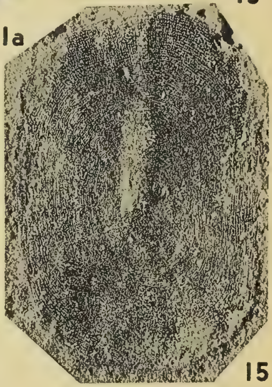
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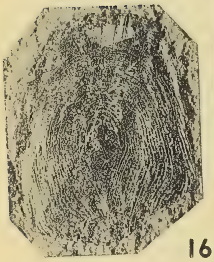
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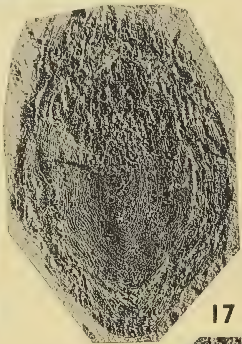
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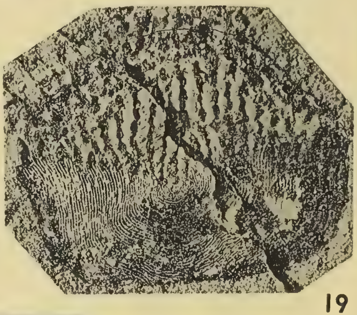
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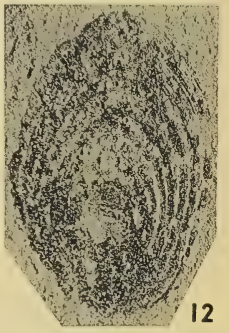
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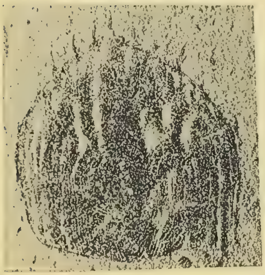
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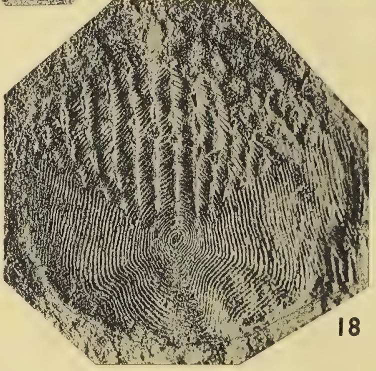
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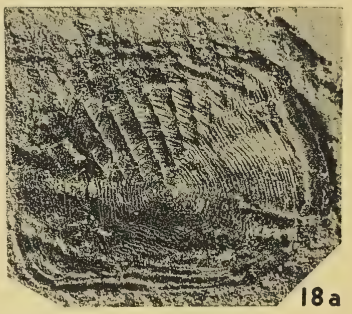
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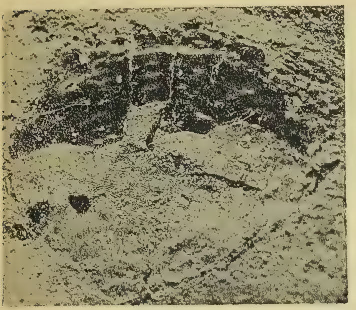
Lower Miocene Fish Scales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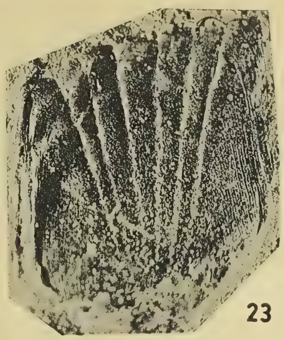
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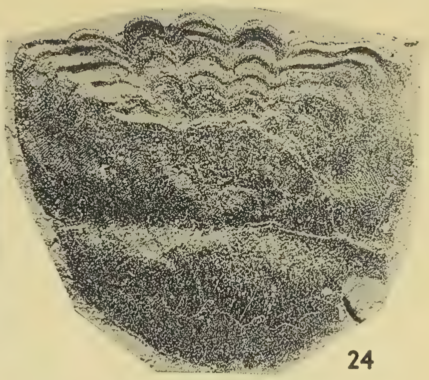
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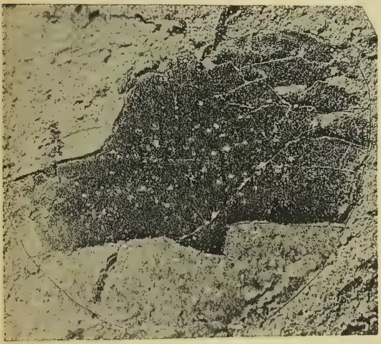
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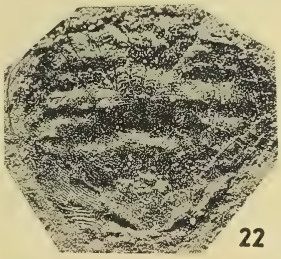
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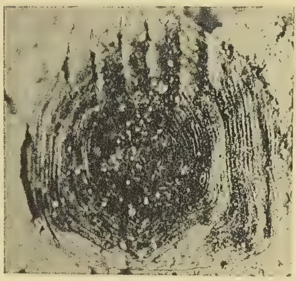
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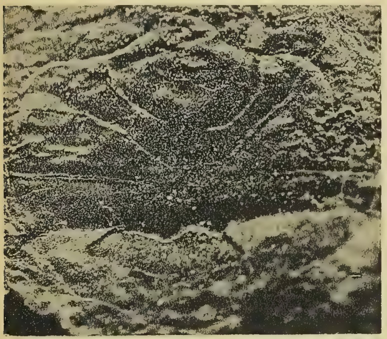
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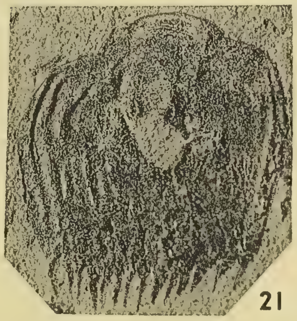
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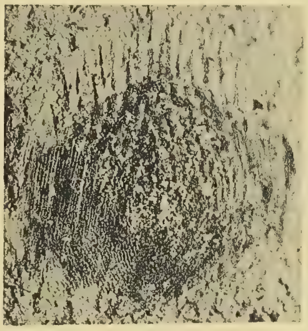
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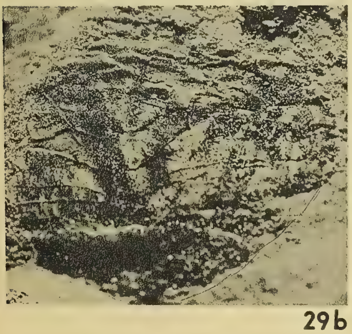
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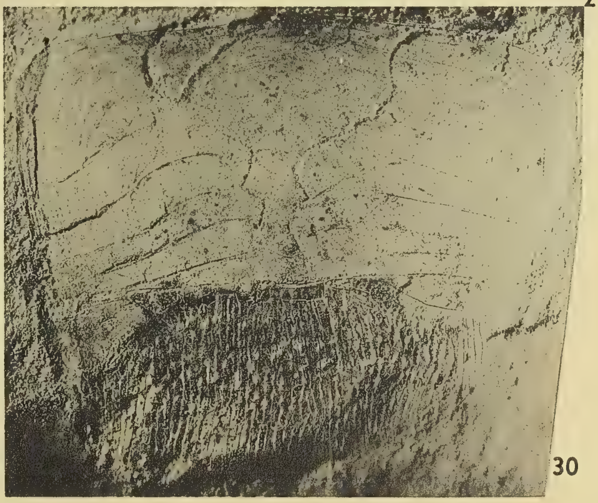
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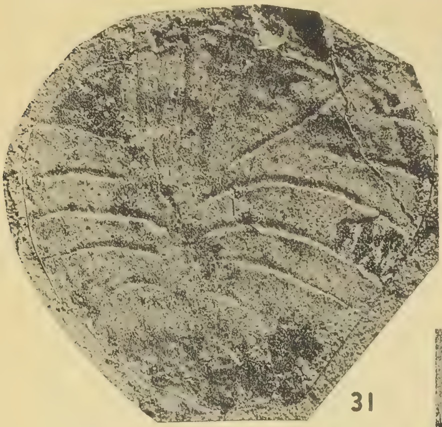
MIDDLE, LOWER, AND UPPER MIOCENE FISH SCALES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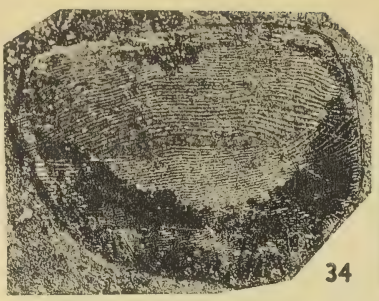
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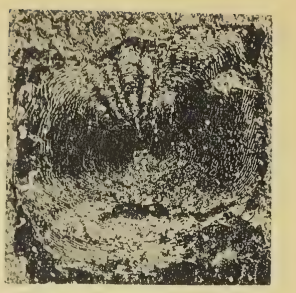
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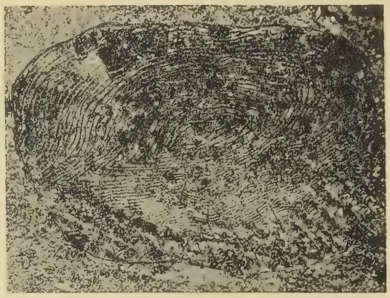
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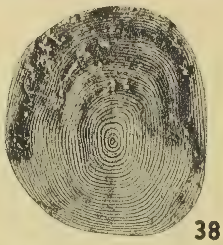
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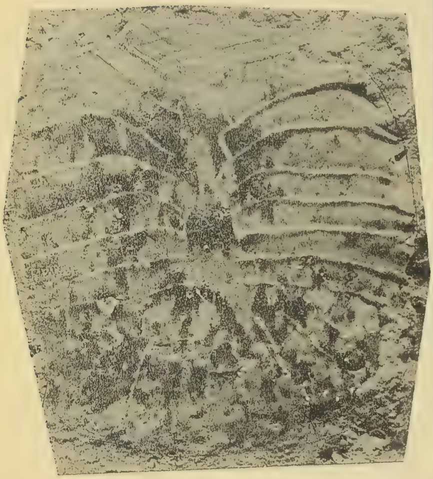
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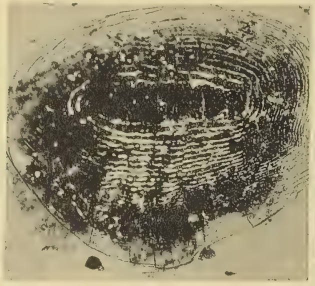
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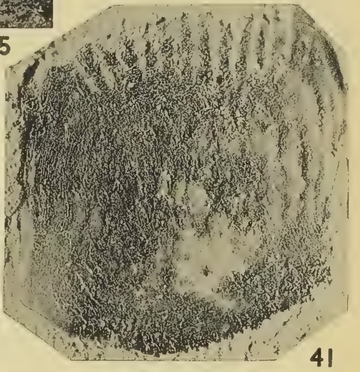
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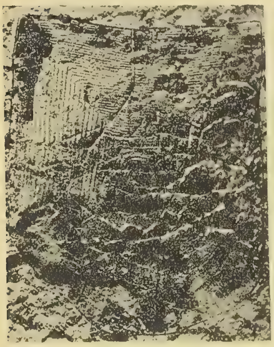
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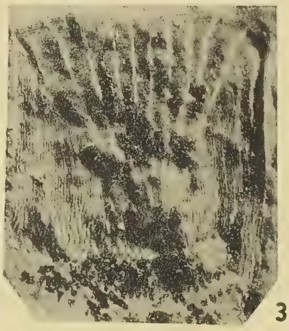
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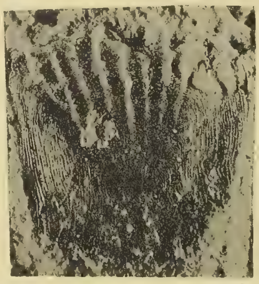
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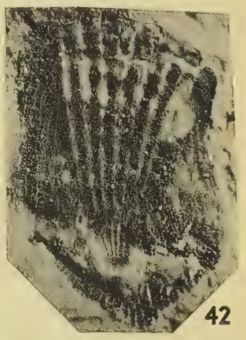
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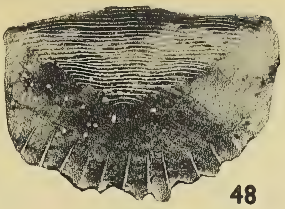

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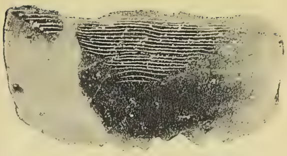

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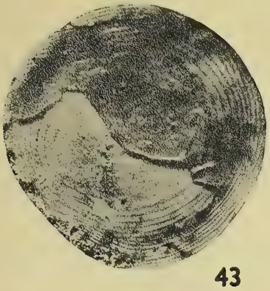

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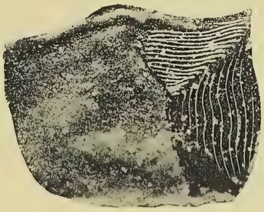

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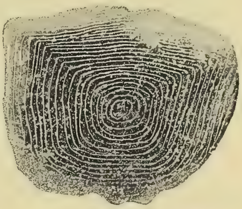

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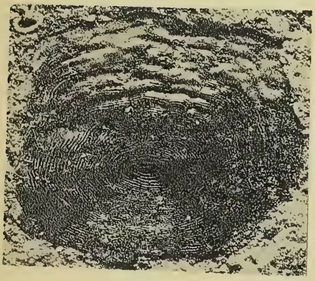

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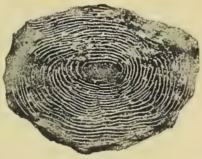

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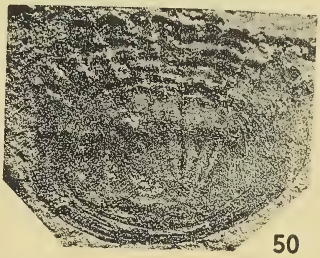

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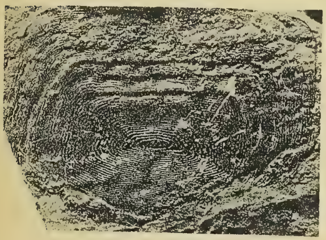

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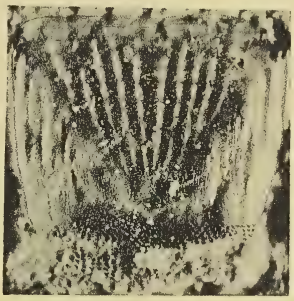

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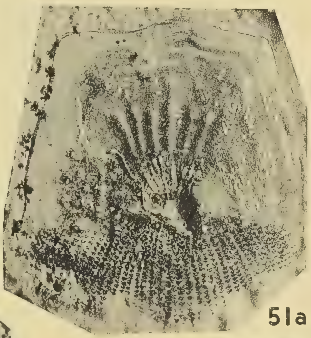

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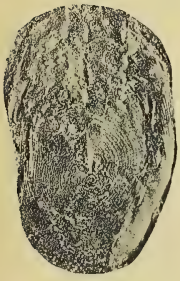

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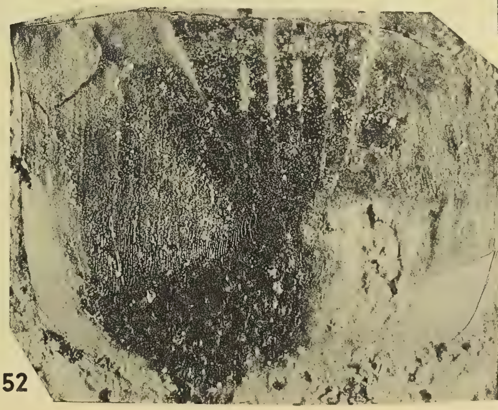

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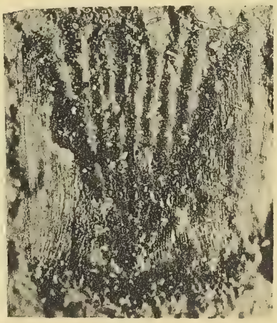

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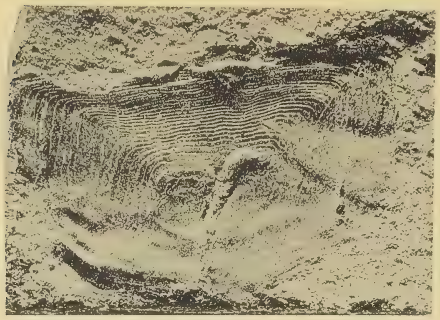
Upper Miocene Fish Scales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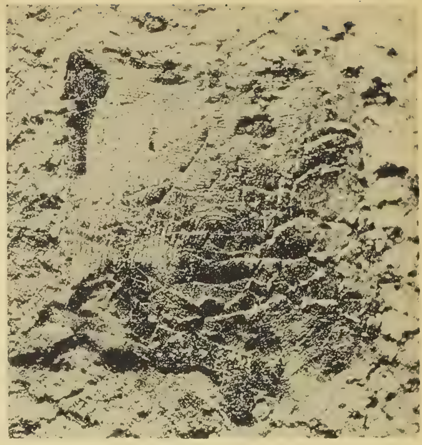
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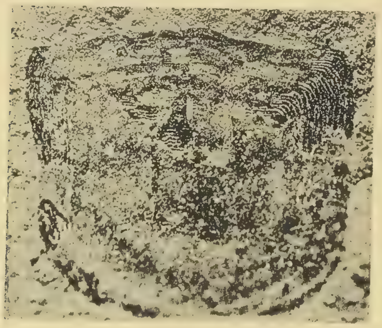
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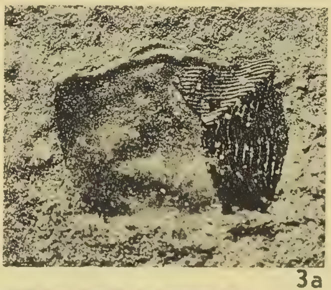
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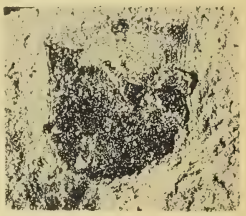
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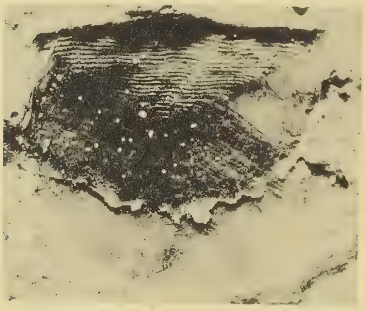
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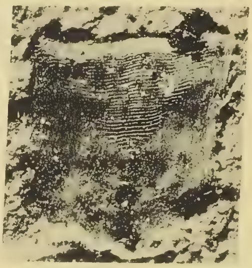
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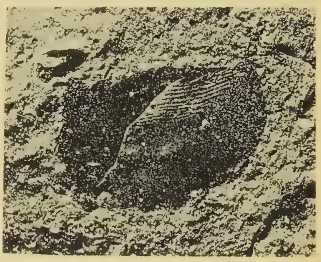
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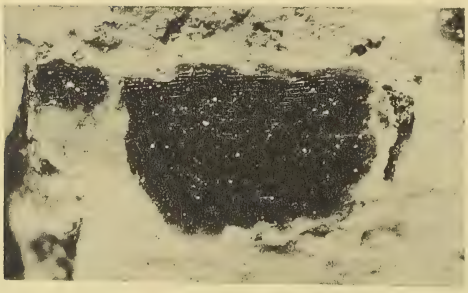
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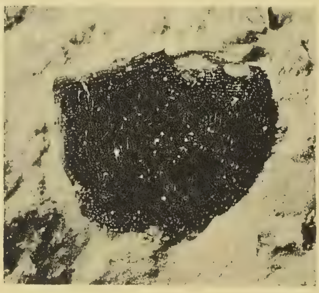
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Tertiary Silversides from California

IV

Some Typical Upper Eogene Fish Scales from California

Lore Rose David

With four plates and ten text figures

[ISSUED JANUARY 25, 1946]

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Some Typical Upper Eogene Fish Scales from California

Introduction

Fossil fish scales belonging to 16 families and to 18 genera from the California Eogene are described in this paper. The majority of the scales come from cores of the Kreyenhagen formation penetrated in oil wells of the San Joaquin Valley. In general, fish scales are plentiful in these strata, whereas there is a sparsity of such remains in the Middle and Lower Eocene.

The fossil specimens come from localities rather widely distributed, but not all occurrences of the Kreyenhagen shale have been sampled for scales. The collection shows great uniformity, so far as abundance of the more typical forms is concerned. It is certain that the important and characteristic fish types of Kreyenhagen age are well represented. The assemblage of scales does, however, contain a number of forms that are rare and too fragmentary to warrant description. Unquestionably, still other types will be found in regions not yet explored for this kind of material.

Special attention has been paid to scales of Upper Eocene age. Many of these, however, range in occurrence into the Oligocene. The Kreyenhagen formation, for example, which furnished most of the material, includes at its type locality rocks of Oligocene and Upper Eocene age (Jenkins, 1931, pp. 142–143). The present paper is concerned only with the Oligocene and Upper Eocene parts of the wells that were the sources of the fossil material. The age of the fauna is stated to be Upper Eogene rather than Upper Eocene and Oligocene, since the treatment of the Oligocene assemblages is very incomplete, and rocks of this age are represented by only thin sections in the region.

A number of new genera and species are established on the basis of scales, since the characters of these structures differ more or less markedly from those of any known form, living or extinct. It must be pointed out that in most instances the fishes to which the scales belong are not known, and the taxonomic position of the genera is frequently doubtful. Diagnoses of the genera have therefore not been given. It seems desirable not to present these diagnoses until such time as the scales and their classification are better known. The genotype species is the only one described for each of the new genera recognized in this paper. Species are described as fully as possible.

Sources of Fossil Material

The following wells in California, enumerated from north to south, were the principal sources of the material:

1. Pure Oil Company, Chowchilla No. 1, Chowchilla district, Sec. 7, T. 10 S., R. 14 E., Mount Diablo base line and meridian.

2. Seaboard Oil Corporation, Oro Loma No. 1, Sec. 12, T. 12 S., R. 11 E., Mt. Diablo B. and M.

3. Seaboard Oil Corporation, Gill No. 1, Sec. 27, T. 12 S., R. 15 E., Mt. Diablo B. and M.

4. Jergins Oil Company, Chaney Ranch No. 1, Panoche district, 330 ft. S. and 330 ft. E. of W. ¼ Sec. 29, T. 14 S., R. 13 E., elevation 392 feet, Mt. Diablo B. and M.

5. Western Gulf Oil Company, Lillis Welch No. 1, Firebough district, 680 feet N. and 990 ft. E. of SW. corner Sec. 26, T. 15 S., R. 12 E., elevation 1150 feet, Mt. Diablo B. and M.

6. Seaboard Oil Corporation, Welch No. 1, 1708 ft. S. and 2036 ft. W. of NE. corner Sec. 10, T. 16 S., R. 13 E., elevation 695 feet, Mt. Diablo B. and M.

7. Amerada Petroleum Corporation, Beer No. 1, Sec. 17, T. 26 S., R. 19 E., Mt. Diablo B. and M.

8. Texas Company, Pioneer Unit Plan Nos. 1 and 2, Sunset district: No. 1, 485.5 ft. S. and 2072 ft. E. of NW. corner Sec. 33, T. 11 N., R. 23 W., elevation 1375 ft.; No. 2, 2207 ft. S. and 2086 ft. E. of NW. corner, Sec. 33, T. 11 N., R. 23 W., San Bernardino base line and meridian.

Acknowledgments

The present study, carried on during 1942 and 1943, is one of several similar investigations conducted at the California Institute of Technology and financed by a number of petroleum companies of California. It is a pleasure to express appreciation to the following individual companies who helped to sponsor these projects: Bankline Oil Company, Continental Oil Company, General Petroleum Company, Richfield Oil Corporation, Shell Oil Company, Standard Oil Company of California, Superior Oil Company, Texas Company, Union Oil Company, Western Gulf Oil Company.

The core material from which the specimens of fish scales were collected was furnished by the Superior Oil Company, the Texas Oil Company, the Western Gulf Oil Company, the Richfield Oil Corporation, and the Ohio Oil Company of California. Dr. Chester Stock has given unstintingly of his time and effort in the supervision of many phases of this work. It is a pleasure also to acknowledge the facilities offered by the paleontological laboratory of the California Institute of Technology. Photographs of scales were taken in the laboratories of the Richfield Oil Corporation, Long Beach, California, and thanks are extended to M. L. Natland for his kind assistance.

Description of Fish Fauna

ORDER EUSELACHII GALEI

Family CARCHARIIDAE

Galeocerdo? sp.

(Text figure 1)

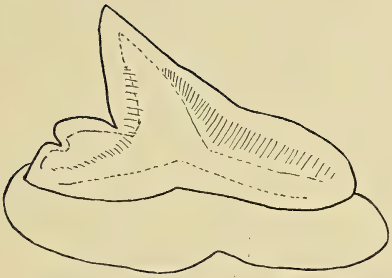

Fig. 1. *Galeocerdo*? sp. Tooth from Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation. Approx. × 9.

A small tooth of a shark, 2.3 mm. long by 3.7 mm. wide, was found in a core of the Oro Loma No. 1 well of the Seaboard Oil Corp., at depth between 3141 and 3170 feet, in the Kreyenhagen formation. The specimen evidently belongs to *Galeocerdo,* or to a related genus. Definite generic identification is difficult on the basis of a single tooth. The tooth is probably different from that of any known species. The small, compressed crown is deeply notched on one side, showing two notches in the basal part; the opposite side is concave. No serrations are observable along the cutting edge. The apex is noticeably deflected to one side. The specimen differs from known teeth of the genus in the concave outline of its unnotched side. *Galeocerdo* ranges from the Upper Cretaceous to the Recent.

ORDER ISOSPONDYLI

Suborder CLUPEOIDEA

Family DUSSUMIERIDAE

Pseudoetringus kreyenhagius, n. g. and n. sp.

(Plate 1, figure 4; text figure 2*e, f*)

L. R. David, Carnegie Inst. Wash. Pub. 551, III, p. 29, pl. 1, fig. 3, 1944.

Type. No. 10321, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.2 mm. long by 5 mm. deep.

Type locality. Seaboard Oil Corp. well, Welch No. 1, at depth of 4037 feet. Kreyenhagen formation.

Description. A small scale which shows the following variations in measurements of length and depth (in millimeters): 5 by 5.1, 4.1 by 6, 4.5 by 5.1, 4.2 by 5, 4 by 5.1, 4 by 5, 3.9 by 4.9. Shape irregularly oblate, with a distinctly marked projection of anterior and posterior margins; edges of dorsal and ventral margins either broadly rounded or more or less straight (fig. 2*e, f*). Scale when preserved (pl. 1, fig. 4) shows considerable thickness, smooth side highly glossy; mold of smooth side shows unusually strong ridges marking transverse radii (David, 1944, pl. 1, fig. 3). If only the impression of the coarse side is present, scale appears thin, for there is nothing to indicate its actual thickness. Scale more or less uniform, apical pole not divided from basal part by complete transverse radius. Basal part characterized by 6 to 8 pairs of strong, closely situated transverse radii, all more or less parallel; uppermost radii become short and more strongly inclined toward center of scale. Apical pole with a few (generally 5) well marked radii directed toward nucleus. Circuli restricted to basal part and small anterior sectors of apical pole at right and left of nucleus. Circuli transverse, very little rounded, widely spaced considering small size of scale; 50 in 1 mm. distance at middle of scale, 40 to 43 at outer margin in scale 4 mm. long by 5 mm. deep. Circuli increase in coarseness toward outer margin of scale, coarsest at dorsal and ventral margins. Outer border of scale folded 2 or 3 times, forming a characteristic strengthened margin.

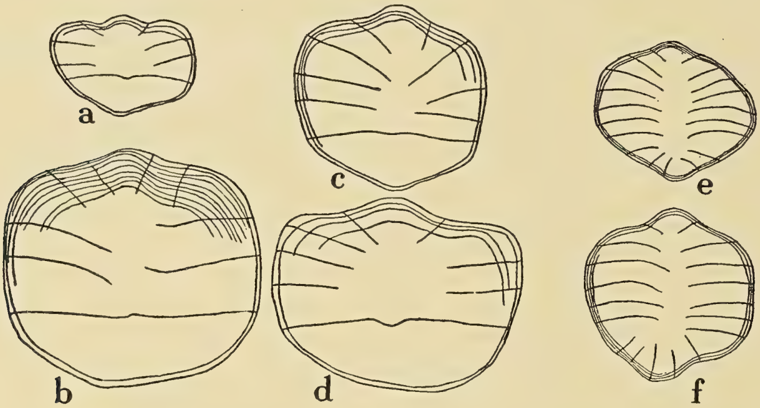

FIG. 2. *a–d, Wisslerius sardinelloides,* n. g. and n. sp. (*a, b*) Jergins Oil Co. well, Chaney Ranch No. 1. (*c, d*) Seaboard Oil Corp. well, Welch No. 1.

e, f, Pseudoetringus kreyenhagius, n. g. and n. sp. (*e*) Seaboard Oil Corp. well, Welch No. 1. (*f*) Pure Oil Co. well, Chowchilla No. 1.

Tumey and Kreyenhagen formations. × 4.

Occurrence. This form of scale is quite abundant in the Kreyenhagen shale, especially in the upper horizons. It was found in cores from the following wells: Seaboard Oil Corp., Welch No. 1, at depth between 4047 and 4245 feet; Jergins Oil Co., Chaney Ranch No. 1, at depth between 3543 and 3669 feet and between 4433 and 4460 feet; Pure Oil Co., Chowchilla No. 1, at depth between 2834 and 2859 feet; and Seaboard Oil Corp., Gill No. 1, at depth between 3988 and 4002 feet.

Relationships. *Pseudoetringus* shows the characters of a clupeoid fish without indication of near relationship to any Recent form. Scales of the Eogene type lack the dividing line between apical and basal parts. This fish was probably not a true herring. In the absence of this line and in the large number of paired transverse radii, the fossil shows some similarity to the Miocene *Etringus.* The latter genus, however, has an entirely different shape and a different apical structure. This small Eogene scale, with its thick, glossy structure, large number of strongly paired transverse radii, and few apical radii converging toward the center, is a distinctive type and may represent an extinct clupeoid family.

Family CLUPEIDAE. Herrings

Wisslerius sardinelloides, n. g. and n. sp.

(Text figure 2*a–d*)

L. R. David, Carnegie Inst. Wash. Pub. 551, III, p. 29, pl. 1, fig. 4, 1944.

Type. No. 10322, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5.2 mm. long by 7 mm. deep.

Type locality. Seaboard Oil Corp. well, Welch No. 1, at depth of 4236 feet. Kreyenhagen formation.

Description. Ovoid to quadrangular with rounded corners. Relatively large, sizes (length and depth, in millimeters) varying as follows: 8 by 9, 6.5 by 8.7, 6.5 by 7, 5.9 by 6, 4 by 5, 4 by 4.9. Basal outline more or less rounded, with middle part projecting; apical border rounded to angular. Apical part comparatively long, comprising one-third of scale length, completely divided from basal part by transverse radius. Basal region generally with 4 pairs of transverse radii, widely spaced at more or less equal distances; in smaller scales only 3 pairs present. Uppermost radii more distinctly oblique, pointing toward center; their direction may have been changed by strong folding of outer margin of scale. Circuli restricted to basal part except for small sectors in uppermost apical part. Circuli transverse; fairly fine in middle of scale, but becoming increasingly coarse toward dorsal and ventral borders with growth of scale; 47 to 50 in 1 mm. distance at nuclear center, 40 at dorsal and ventral borders of scale of 7 mm. depth, 39 in scale of 9 mm. depth, and 35 in scale of 10 mm. depth. Apical pole almost smooth, indistinct radii showing at apical border. A number of folds are seen around outer border of scale, these especially numerous on basal margin. Scale usually found with separated apical and basal parts.

The new genus is named for Mr. Stanley G. Wissler, paleontologist of the Union Oil Company, California.

Occurrence. The scale is abundant in the Tumey and upper Kreyenhagen. Well preserved specimens are commonly found in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Smaller scales of the same type are abundant in the same well from 3624 to 3864 feet. More or less fragmentary specimens are found from 4304 to 4407 feet. The scale is also abundant in the Seaboard Oil Corp. well, Welch No. 1, at depth from 4037 to 4236 feet, and in many others.

Relationships. In the shape of the apical and basal regions, and in the arrangement of the paired transverse radii, relationship is shown to *Sardinella,* a genus widely distributed today in warm seas. Close similarity is also shown to the related genus *Opisthonema,* an inhabitant of warm coastal seas. *Opisthonema libertate* from the Galapagos Islands has scales quite similar to the fossils. *Sardinella* has a greater number of paired transverse radii and more pronounced apical radii. *Sardinella sirmi* from the Philippine Islands and *S. clupeoides* from British North Borneo seem to be exceptions, but their radii are much less regularly arranged and even smaller in number than in almost any of the Eogene scales. The numerous folds along the outer margin, so characteristic of the fossil scales, are not present or are only faintly indicated in scales of Recent fish. The folds appear to develop as a result of compression of the scale during entombment in the rock. There is not much doubt that the Eogene genus is related to the group of modern herrings comprising the genera *Sardinella* and *Opisthonema.* It differs to some degree, however, from all known living forms. This scale occurs in several groups of strata of the Kreyenhagen shale, but varies noticeably in size and to some degree also in shape. The type of scale that comes from the Seaboard Oil Corp. well, Welch No. 1, is of medium size and oval in shape. The well preserved scales of the genus found in the uppermost Kreyenhagen of the Jergins Oil Co. well, Chaney Ranch No. 1, are rounded, and are distinguished by their very large size. These may represent a different species, or a large variety. This part of the stratigraphic column correlates with the so-called Leda zone, and is higher in the section than that containing the remaining material studied. At other stratigraphic horizons the scales average much smaller.

? **Alosa ganolytoides,** n. sp.

(Text figure 3)

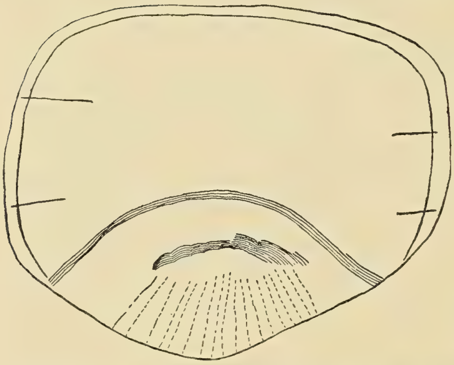

FIG. 3. ? *Alosa ganolytoides,* n. sp. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation. × 4.

Type. No. 112, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 11.2 mm. long by 13.5 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3170 and 3200 feet. Kreyenhagen formation.

Description. Only a few specimens are known so far; a second large scale, similar to the type specimen, measures 10.5 mm. long by 11.5 mm. deep. Two smaller specimens are also available. Scales large, oblong, shadlike; basal part comprises two-thirds of scale, not distinctly separated from apical part. Numerous fine basal circuli, transverse to rounded, ending at dorsal and ventral margins; approximately 39 to 42 in 1 mm. distance. Circuli form irregular pattern and are not everywhere parallel. Pattern of basal radii not clearly shown; transverse radii present but not completely visible. Apical pole small, not always occupying entire apical margin, but restricted to a smaller sector. Apical radii form fine, broken tubercular lines; these are not so strong nor are the tubercles so numerous as in the Miocene *Ganolytes.* Not quite 4 radii in 1 mm. distance.

Occurrence. In addition to the type, there are three scales from the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 4304 and 4330 feet.

Relationships. The scale shows resemblance to comparable structures seen in forms related to *Alosa,* as well as in the Miocene genus *Ganolytes. Alosa ganolytoides* is characterized by fine tuberculated and elevated radii marking the apical pole. These are considerably finer than in *Ganolytes,* but more distinct than in any of the Recent scales.

Suborder SALMONOIDEA

Family COREGONIDAE

Parastenodus gillensis, n. g. and n. sp.

(Plate 4, figure 4)

Type specimen. No. 110, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 5.2 mm. long by 3.9 mm. deep.

Type locality. Seaboard Oil Corp. well, Gill No. 1, at depth between 3852 and 3863 feet. Kreyenhagen formation.

Description. Round to elongate scales of medium size; a second specimen 4.1 mm. long by 5.2 mm. deep. Concentric circuli throughout scale, nowhere distinctly folded, showing slight deviations and irregularities almost everywhere. Type shows 2 fold-like curvatures of circuli at basal pole; a second scale more regularly concentric; circuli most distantly spaced toward apical pole (17 in 1 mm. distance), most closely spaced near dorsal and ventral borders (27 to 28 in 1 mm. distance). Nucleus acentral. Smooth side of scale marked by a number of tubercles in places. Annuli indistinctly shown, type probably a scale in its third year.

Occurrence. In addition to the type, only one scale was collected, in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3229 and 3242 feet.

Relationships. The relationships of this salmonoid scale are presumably with the Coregonidae, as is indicated by the more or less concentric circuli that occupy the entire scale, the acentral nucleus, and the structure of the circuli. Scales of *Stenodus mackenzii* from Alaskan waters show irregularities of the circuli similar to those in the fossil form, although the Recent scales are considerably larger and more rounded. So far as the fossil is known, it cannot be assigned to any living genus. *Stenodus* seems to be the nearest living type.

Beckius plicatus, n. g. and n. sp.

(Plate 4, figure 5)

Type. No. 111, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 4.5 mm. long by 4.5 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Tumey formation.

Description. Scale almost quadrangular, broadening toward apical region. Basal part with sharp-angled folds, 2 in diagonal of laterobasal angles, 2 more central than these, with folds forming triangular projections of border. Nucleus central, surrounded by concentric circuli which rapidly increase in size and show typical folding of the basal part almost to the most central and smallest circuli. Circuli coarse, finest toward basal pole, 18 in 1 mm. distance toward basal border; circuli increase noticeably in width toward apical part of scale and along dorsal and ventral borders, 12 in 1 mm. distance toward apical border. Type evidently a lateral-line scale, apical circuli divided in middle.

The new genus is named for Mr. R. Stanley Beck, paleontologist, Bakersfield, California.

Relationships. The structure of the scale indicates relationship with the Coregonidae, although this seems to be less certain than in the preceding form. The fossil shows similarities to *Leucichthys nigripinnis cyaenopterus* from Lake Superior. In *Leucichthys,* however, the basal folds are not so well developed, nor are they symmetrical. The circuli in *Leucichthys* grow considerably wider in the apical region as in the fossil, but they remain close together along the dorsal and ventral borders. Also, in the Recent scale these structures do not show the coarseness seen in the much smaller fossil. The latter scale, with basal part divided into sharp angular folds and with circuli widening considerably toward the apical part, can be readily distinguished. A modern scale showing resemblance to the fossil form does not appear to be known, and the well preserved specimen apparently belongs to an extinct group related to the Coregonidae.

Family CYCLOLEPIDAE, new family

Cyclolepoides tuberculatus, n. g. and n. sp.

(Plate 2, figures 4, 5)

L. R. David, Carnegie Inst. Wash. pub. 551, III, p. 31, pl. 2, fig. 15, 1944.

Type. No. 10331, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5 mm. long by 3.5 mm. deep.

Type locality. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 1851 and 1858 feet. Kreyenhagen formation.

Description. Irregularly rounded to oval scales, generally very large and thick. Occasionally small scales are present, the latter belonging possibly to a different species. Size (length and depth, in millimeters) varying as follows: 2 by 1.9, 3.1 by 3, 2.9 by 2.5, 3.9 by 2, 6.1 by 5, 7 by 5.9, 9 by 6.1, 12 by 9. Scales show simple structure, with fine concentric circuli equally marked on entire specimen. Nucleus central to subcentral, depending on shape of scale. Scale very thick. Distinct differences between coarse and smooth sides. Even and glossy in parts of smooth side (pl. 2, fig. 4); other parts marked by irregular furrows and cavities, penetrating more or less into scale, but not perforating it. Checkerboard pattern on coarse side penetrating in places through scale, especially along outer border, marking smooth side of scale with regular concentric rows of elevations that are coarser than circuli. Coarse side of scale (pl. 2, fig. 5) marked by concentric ridges of circuli, showing irregularities in places. Circuli usually marked by rows of pointed tubercles set on their upper edges. Tubercles arranged in diagonal rows, giving impression that diagonal cross-rows are present, and forming a checkerboard pattern which is distinct along outer border. Number of circuli variable, circuli most delicate in center; rings of fine and coarse circuli alternating toward outer border. The following counts in different specimens give numbers of circuli in 0.1 mm. distance found in successive rings from center of scale to outer border: Eogene scale with diameters of 7 and 8 mm.: 10, 7, 11, 7. Regenerated Eogene scale with diameters of 7.5 and 9 mm.: 7, 9–10. Eogene scale with diameters of 3 and 2.5 mm.: 10, 6, 7. Eogene scale with diameters of 1.9 and 2 mm.: 10, 7. Saucesian scale with diameters of 10 and 12 mm.: 13, 11, 8, 5½. Saucesian scale (David, 1944, pl. 2, fig. 15) with diameters of 6 and 4.9 mm.: 9, 11, 8, 6.

Occurrence. This scale is very abundant at particular horizons wherever found in the Upper Eocene. It was collected in the Eocene Kellogg shale of the Mount Diablo area. It occurs abundantly in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 1087 and 1858 feet; in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 4304 and 4360 feet; in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 2800 and 3220 feet; in the Seaboard Oil Corp. well, Gill No. 1, at depth between 3935 and 4002 feet; in the Texas Co. well, Pioneer Unit Plan No. 1, at 8093 feet and deeper; in the Texas Co. well, Pioneer Unit Plan No. 2, at 9353 feet and deeper; and in other wells. The scale is not restricted to the Eogene, for it is found higher in the stratigraphic column, occurring in the Upper Zemorrian–Lower Saucesian. Here it is occasionally present, but is not abundant.

Relationships. Cretaceous scales of oval shape, with concentric circuli and subcentral nucleus, and without radii and ctenoid structures, have been assigned to the genus *Cyclolepis* (Cockerell, 1919). The Californian Eogene *Cyclolepoides* shows fundamentally the same structure. It is included in the Salmonoidea, following Cockerell's classification (1919, p. 181). This group of fishes shows for the most part the same type of simple scale as that so well represented by the living *Stenodus mackenzii.* The scale of *Cyclolepoides* differs in the fineness of its circuli, and in the regularly placed tubercles which follow the course of the circuli, giving the scale its peculiar pattern. The thick scales, with smooth side occasionally deeply furrowed, suggest a primitive condition, and they may represent an extinct group. These characters give the scale a typical aspect and make it easily distinguishable from all other fossil forms as well as from living Salmonoidea. It is questionable whether the scale represents a true salmonid fish. No other group is known to the writer, however, to which it might belong. The migratory habit of the form, as pointed out below, suggests a relationship to the salmons.

There can be little doubt that this fish was migratory. Annular rings of more or less crowded circuli can be seen on almost every scale, their extent varying in different scales. The length of time represented by such rings cannot be stated. The circuli nearest the middle are the densest, and those toward the outside are the least crowded, a fact which indicates that life started in fresh water and ended in a marine environment. Cockerell likewise regards the Cretaceous *Cyclolepis* as probably having had migratory habits. It is possible that the Cretaceous and Eocene forms represent a group of salmons that are extinct today. The location and depth where modern salmon feed, while in the sea, have not been definitely determined. Salmon have been reported, however, far out in the sea, beyond the continental shelves, and it is evident that feeding salmon frequent the waters of the open sea as well as those of the immediate coast (Davidson and Hutchinson, 1938, pp. 667 ff.).

The scale of *Cyclolepoides* is abundant in the Upper Eogene and may be an indicator of Eocene age. It has been found, however, in occasional core samples as high as the Lower Miocene.

ORDER INIOMI

Family ? CHLOROPHTHALMIDAE

Iniomus fossilis, n. g. and n. sp.

(Plate 1, figure 1)

Type. No. 10333, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.1 mm. long by 4 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Tumey formation.

Description. Type and only specimen quadrangular in shape, with pronounced basilateral angles. Basal margin curved and projecting at middle; dorsal and ventral margins straight. Nucleus subapical. Basal region completely occupied by fine parallel circuli, concentric with basal, dorsal, and ventral margins; strongly bent in basilateral angle; circuli numerous, 34 to 35 in 1 mm. distance at basal border. No folding recognized. Most central circuli (about 6) wide. Apical pole almost restricted to apical margin, smooth, equipped with one row of relatively wide, probably flattened spines; 17 or 18 spines in less than 1 mm. length.

Discussion. The type is the only specimen thus far known, and is well preserved.[1]

Relationships. The scale shows the characters of the Iniomi, as indicated by the structure and position of the spines, and also by the arrangement of the circuli and the nuclear center. The circuli, however, are quite numerous for the group. The nearer relationships of the form are uncertain. It does not conform exactly to any one kind of scale in the available collections, but seems nearest to the Chlorophthalmidae in general structure. A considerable number of scales of genera of the Iniomi are still unknown, and it is possible that in future some near relatives of the fossil will be found among the living members of the group.

ORDER SYNENTOGNATHI

Family ? SCOMBERESOCIDAE. Skipjacks or Garpikes, Sauries

Praescomberesox pacificus, n. g. and n. sp.

(Plate 2, figure 3; plate 3, figure 2)

Type. No. 10325, Calif. Inst. Tech. Vert. Pale. Coll. Scale 7 mm. long by 7 mm. deep.

Type locality. Seaboard Oil Corp. well, Gill No. 1, at depth between 3895 and 3907 feet. Kreyenhagen formation.

Cotype. No. 10326, Calif. Inst. Tech. Vert. Pale. Coll. From Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 1748 and 1761 feet. Kreyenhagen formation. Scale 4.1 mm. long by 7 mm. deep.

Description. Scale type A (pl. 3, fig. 2): Subquadrangular, with round apical pole. All specimens of nearly same size: 8 by 7 mm., 6 by 6.5 mm., 6.5 by 7.1 mm. Basal border straight, meeting dorsal and ventral borders at about a right angle; apical border rounded. Circuli form only pattern on scales; these are transverse throughout scale, increasingly coarse toward basal margin, fine in apical region. Nucleus or center of scale between basal and apical parts, not clearly marked. Circuli not parallel, but slightly curved or oblique in places, sometimes bent at exterior border, directed toward apical end beyond more centrally located circuli. Latter may be shortened. Such structures are asymmetrical, since they do not reach same level at dorsal and ventral borders. Folds distinct along basal border, and folding of entire scale parallel to margin of upper half of scale, strongest along exterior border.

Scale type B (pl. 2, fig. 3): Measurements (in millimeters) of length and depth vary as follows: 4.1 by 7 (cotype), 4 by 6.5, 2.1 by 4. Scales much deeper than long, much shorter than those described under type A. Basal and apical borders more or less straight, dorsal and ventral margins rounded; pattern of scales more or less similar to that of type A, with transverse circuli coarser toward basal region. Nucleus hardly distinguishable in some scales; better shown in smallest scale, which may come from one extremity of body. Pattern of circuli shows irregularities toward outer margin as in type A scales. Scale not folded.

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[1] This type of scale has been found to be very abundant in the Middle Eocene Llajas formation of Simi Valley.

Occurrence. Though this scale is not very abundant, it was found repeatedly in the Kreyenhagen. Type A scales occur in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3548 and 3597 feet, and in the Seaboard Oil Corp. well, Gill No. 1, at depth between 3895 and 3907 feet. Type B scales were found in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 1748 and 1761 feet; in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3220 and 3239 feet; and in the Seaboard Oil Corp. well, Gill No. 1, at depth between 3895 and 3907 feet.

Relationships. This interesting scale is of unusual type, and easily recognized by its characteristic shape. The type A scale is rather long in proportion to its depth, the basal border is straight with sharp corners, and the apical pole is rounded. The scale is folded several times along a line parallel to the basal border. All circuli are more or less transverse, and the center of the scale, with nucleus, cannot be readily distinguished, if present at all. No modern scale of comparable structure is known to the writer. Scales with transverse circuli that are coarse in the basal part and fine toward the apical pole, and with central nucleus, are found in the Scomberesocidae among the Synentognathi. Similar scales are also found among the Carangiformes, but in this group they are more delicately constructed and smaller. The Eocene scales are more like those of scomberesocid forms. The scales of the long and slender *Scomberesox* of today are small and ellipsoid, the edges are always rounded, and they differ noticeably in shape from the large, sharp-edged fossil specimens. Greater resemblance is seen in the arrangement of the circuli, the central circuli being parallel in *Scomberesox* and the nucleus hardly distinct; the basal circuli are coarse, with the apical ones becoming progressively finer. In the Recent genus the circuli do not show irregularities toward the outer margin as in the fossil. It is quite conceivable, however, that such irregularities existed in related forms, and that the larger size and different shape of the fossils are responsible for such differences as are shown by the circuli. The scales of *Scomberesox* are comparatively robust, as in *Praescomberesox.*

The type B scales show considerable resemblance to those of type A, and their differences are probably due to differences in position on the body. Nearly all genera of the order Synentognathi show a distinct differentiation between the scales of the upper and lower parts of the body.

Since no further information is available to assist in the classification of this Eocene form, it is tentatively regarded as having a relationship with the Scomberesocidae.

Family HEMIRAMPHIDAE. Halfbeaks

Hemiexocoetus eocenicus, n. g. and n. sp.

(Plate 2, figures 1, 2; plate 3, figure 1; text figure 4)

Type. No. 10324, Calif. Inst. Tech. Vert. Pale. Coll. Scale 9 mm. long by 10 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3170 and 3200 feet. Kreyenhagen formation.

Description. Hemiramphidae and Exocoetidae show a remarkable differentiation in shape of their scales according to position in dorsoventral direction. Scales from different positions on the main part of the body are found in the same relative abundance in the geologic sections. The most typical scales of *Hemiexocoetus* are described below, with an indication of their probable position on the body.

Lateral scale near vertebral spine is illustrated in figure 4*a,* and in plate 2, figure 2. Largest scales on body are rounded to ovoid and show the following variations in measurements (in millimeters) of length and depth: 10 by 11, 10 by 10.8, 9.8 by 10, 8 by 7.1, 5.9 by 7.5, 6 by 7.1. Figure 4*a* depicts outline of typical scale of group; plate 2, figure 2, a regenerated scale with smooth center. A variable number of basal folds are present, rarely only 1, usually 5, of unequal width (fig. 4*a*). Shape and structure of folds very irregular; generally in middle of basal margin, sometimes spreading over major part of basal margin; extending to focus of nucleus. Nucleus occupies a central area on the scale. It is ovoid in shape, much deeper than long, with irregular outline. Nucleus divides basal and apical groups of circuli, with apical circuli much more closely situated. Circuli of the two groups meet in more or less pronounced angles at middle line of scale. Circuli in central area irregular, their distances widening; basal circuli follow curvature of folds; external circuli end in dorsal and ventral borders; more central ones may or may not join corresponding apical circuli. Apical circuli more strictly transverse, more concentrated than basal ones, concentration increasing toward apical margin. Regenerated scales not rare; showing smooth central part of scale of different size.

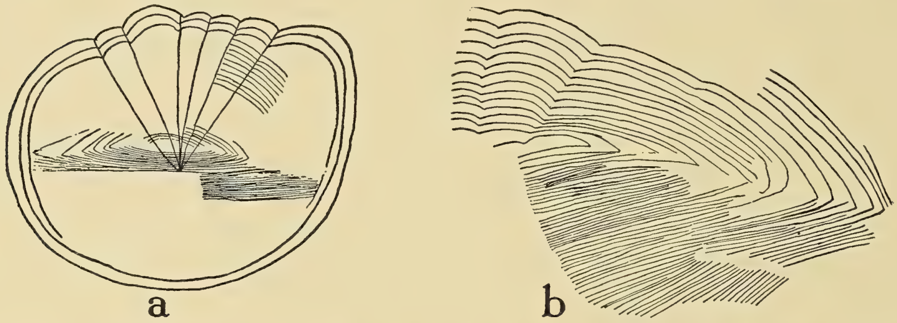

Fig. 4. *Hemiexocoetus eocenicus,* n. g. and n. sp. (*a*) Jergins Oil Co. well, Chaney Ranch No. 1. × 15. (*b*) Right side of central circuli. Western Gulf Oil Co. well, Lillis Welch No. 1. × 19.
Kreyenhagen formation.

Dorso- or ventrolateral scales (pl. 3, fig. 1) ovoid, comparatively small; measurements (in millimeters) 6 by 5.1, 4 by 5, 3 by 5.2. All types of variation exist between this type of scale and that described above. Usually only 1 basal fold is present, basal margin is distinctly scalloped. Nucleus nearly central, surrounded by concentric trapezoidal circuli. Basal circuli transverse in center, strongly curved in fold, acutely curved in laterobasal angles; angles between basal and apical circuli regularly parallel; apical circuli transverse and crowded.

Ventrolateral scales (pl. 2, fig. 1) readily distinguished by their length, which is greater than the depth: 8 by 6.3, 7 by 6, 6 by 5.3 mm. Three to 4 basal folds usually present; a number of transverse and apical radii further divide the scale. Nucleus low, below center; division between basal and apical circuli strongly pronounced. The two types of circuli meet in acute angles on a diagonal in lower half of scale; central ends of circuli widen irregularly (fig. 4*b*). Apical circuli crowded.

Small scales of same form and apparently from extremities of body are occasionally found. These show smooth centers, irregularly rounded outer circuli, and an irregular number of folds on basal border.

Number of circuli variable. The following values are found in typical specimens: in scale 9 mm. long by 10 mm. deep, basal circuli number 11 to 12 in 1 mm. distance, apical circuli 38 to 39; in scale 4 mm. long by 5 mm. deep (pl. 3, fig. 1), basal circuli 18, apical circuli 32; in scale 8 mm. long by 6.3 mm. deep (pl. 2, fig. 1), 10 in 1 mm. distance from basal border, 14 near center of basal part, 40 near apical border.

Occurrence. This scale is abundant in the Kreyenhagen and appears to be evenly distributed throughout the formation. It was found in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 1087 to 1859 feet and lower; in the Seaboard Oil Corp. well, Oro Loma No. 1, between 3170 and 3200 feet; in the Jergins Oil Co. well, Chaney Ranch No. 1, at 4278 feet and lower; in the Pure Oil Co. well, Chowchilla No. 1, at 2834 feet and lower; in the Seaboard Oil Corp. well, Gill No. 1, at 4004 feet; and in the Texas Co. well, Pioneer Unit Plan No. 1, at 8021 feet and lower.

Relationships. Hemiexocoetus is related to the Hemiramphidae and also to such forms of the primitive Exocoetidae as *Evolantia microptera.* There is no special relationship to any one form. The majority of scales show distinctly marked acute angles where the basal and apical circuli meet along a dorsoventral diagonal. This feature is more characteristic of the Hemiramphidae. In the Exocoetidae the circuli are more concentric, with median angle hardly distinct. The shape of the relatively large rounded scales of *Hemiexocoetus* agrees more with that of scales of the Exocoetidae than of the Hemiramphidae. In the latter they are nearly always deep and short. The circuli of the apical region are well marked in all the fossils, whereas the apical pole in many specimens of modern forms is often smooth or provided with only a few widely spaced lines. This may be a primitive feature in *Hemiexocoetus,* the disappearance of the apical circuli in modern scales being due to degeneration.

The fossil species shows a variety of different types of scales, similar to those seen in Recent members of the group, but not identical with those found in any one genus. It seems quite clear that *Hemiexocoetus* is an extinct type, ancestral to some of the Hemiramphidae and less advanced Exocoetidae. It may well be a primitive flying fish, like *Evolantia microptera* from the Galapagos Islands, to which it shows some similarity. The fishes of related families are pelagic swimmers; some of them go far out into the open sea (Breder, 1938, p. 114) and are truly oceanic forms. Others are inhabitants of neritic environments. It is interesting to note that Murray (1912, p. 747) regarded the Synentognathi as the most numerous surface fish which were taken on his southern route over the Atlantic Ocean. The flying fishes are most abundant in tropical and subtropical regions. Some genera, however, are found as stragglers beyond these zones, for example those which range northward to Point Conception on the Pacific Coast of North America.

Incertae sedis

A related form with scale 21.2 mm. long by 24.5 mm. deep, Univ. Calif. Mus. Pale. Coll., from U. C. locality A3290, was collected in the Upper Eocene Kellogg shale in the Mount Diablo area. This single large scale evidently represents a true flying fish.

ORDER ANACANTHINI

Family BREGMACEROTIDAE

Bregmaceros kreyenhagus, n. sp.

(Plate 1, figure 5)

Type. No. 10327, Calif. Inst. Tech. Vert. Pale. Coll. Scale 1.2 mm. long by 1 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth of 3220 feet. Kreyenhagen formation.

Description. Small U-shaped scales, longer than deep or as deep as long. Measurements (in millimeters) of length and depth vary as follows: 2.2 by 2, 2 by 1.8, 2 by 1.7, 1 by 0.9. Basal pole truncate, apical pole rounded, nucleus almost central, lemon-shaped, and projecting with sharp angle into basal part. Circuli concentrically rounded in apical region, corresponding to apical outline of scale. Central circuli extend beyond nucleus into basal region, where they straighten and are almost perpendicular to basal border. Outer circuli end abruptly in dorsal and ventral margins. Apical part of circuli marked by very fine crosslines; these, however, are not very distinct; tubercles present, covering center of scale, in only a few specimens. Basal circuli sometimes disconnected in fossil scales (pl. 1, fig. 5). 23 or 24 apical circuli in 0.5 mm. distance.

Occurrence. Abundant scales of this type were found repeatedly in cores from the Kreyenhagen formation: in the Seaboard Oil Corp. well, Oro Loma No. 1, at depth between 3220 and 3282 feet; in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth between 2082 and 2100 feet; in the Jergins Oil Co. well, Chaney Ranch No. 1, at 4330 feet and lower.

Relationships. These characteristic fossil scales are easily identified as like the scales of the modern *Bregmaceros.* It is interesting to note that scales of such small size can be easily recognized in fossiliferous strata; in the Western Gulf Lillis Welch well they actually occur in comparatively coarse sandy shale. The fossil scales were compared with scales of *B. atlanticus* from Tortugas, Florida, and with the descriptions by Peabody (1931, p. 145). The general pattern of fossil and Recent specimens is very much the same. The Kreyenhagen species is readily distinguished from *B. atlanticus,* whereas Peabody finds the two Recent species very similar, except for external shape. The fossil species has much more crowded circuli than *B. atlanticus,* for in the former there are 11 to 14 circuli in 0.5 mm. distance in the basal part, whereas there are 9 to 10 in the Recent form. Similarly, in the apical region there are 23 to 24 circuli to 0.5 mm. in the fossil, and 16 to 17 in the living species. The basal circuli, furthermore, are separated by interspaces in the modern scale, whereas they are in touch with each other in the fossil. In the Recent scale the apical circuli have heavier cross sections, and larger tubercles are more generally distributed in the central part. It is not certain how these characters compare with those of *B. bathymaster* = *macclellandii.* In Peabody's drawing the basal circuli appear to be denser and the apical circuli are coarser than in the fossil form.

Bregmaceros is characteristically an inhabitant of medium depths (90 to 300 fathoms) in the open sea. The genus has been taken in shallower water (20 to 40 fathoms) extending to the margin of the neritic zone. Longley (Longley and Hildebrand, 1941, p. 35) assumes that the genus is a bottom dweller, since it has been caught repeatedly in dredges. The young especially have been found near the surface, however, and the genus is thought to be a surface dweller by some authors. *Bregmaceros* occurs in warm waters and has a wide distribution. In the eastern part of the Pacific basin it is found off Panama and off the coast of Mexico as far north as Acapulco.

ORDER BERYCOIDEI

Family POLYMIXIIDAE. Barbudos

Parapolymixia californica, n. g. and n. sp.

(Plate 1, figure 6; text figure 5)

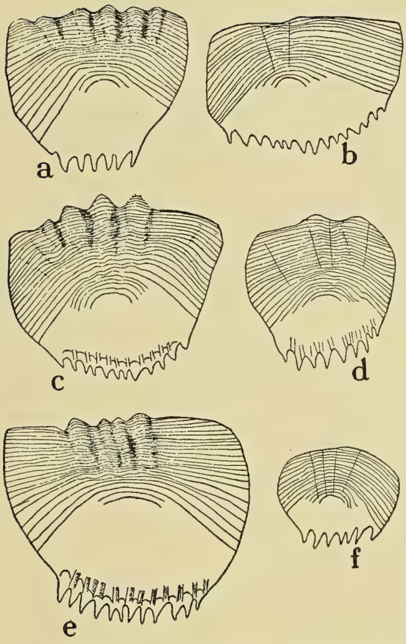

Fig. 5. *Parapolymixia californica,* n. g. and n. sp. Western Gulf Oil Co. well, Lillis Welch No. 1. Kreyenhagen formation. × 10.

Type. No. 10323, Calif. Inst. Tech. Vert. Pale. Coll. Scale 2.8 mm. long by 3 mm. deep.

Type locality. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 1087 to 1106 feet. Kreyenhagen formation.

Description. Small to medium-sized scales with length and depth measurements (in millimeters) varying as follows: 4 by 4.1, 3.9 by 4.1, 3.9 by 3.9, 3.2 by 3.7, 3 by 3.5, 3.2 by 3.2, 3 by 3.1, 3 by 3, 2 by 2.5, 1.9 by 2.1. Basal margin almost straight, apical margin broadly rounded, continuous with dorsal and ventral margins, anterolateral angle pronounced. Basal region with an irregular number of folds. These do not reach nucleus, but extend from one-third to one-half length of basal region; folds stand high and as a rule do not come in contact with one another, but are separated by an unfolded section of circuli. Circuli curved in folded area, but not sharply divided into sections as in the majority of percomorph scales. In larger scales, folds generally situated in center of anterobasal part. In scales of more normal size, folds distributed irregularly over all of anterior part of scale, with the central folds more pronounced. Nucleus in center of scale or slightly toward apical end. Circuli restricted to a part of basal region. Circuli above nucleus incomplete, not reaching dorsal and ventral margins, curved, with anterolateral angle not always marked. Circuli toward base parallel to nucleal ones in center, continuing toward dorsal and ventral borders after a sharp, often angular turn in apical direction, distance between circuli widening toward outer margin. Circuli near basal border more or less completely transverse, with short curves at dorsal and ventral ends; these circuli separated by less distance than central ones; approximately 12 circuli in 1 mm. distance near basal border, 10 near center of scale, in specimen 3.9 mm. long by 4.1 mm. deep. Apical pole provided with at least one series of well defined spines, supported by apical keels in apical ridges. Occasionally a double row of spines can be observed. Spines vary in length, evidently not always completely preserved. Scale, when preserved, often clear brown, glossy, sometimes black, with luster of mother of pearl, or replaced by pyrite.

Occurrence. This scale is very abundant everywhere in the Upper Eocene of the San Joaquin Valley, and is a good horizon marker for the deeper parts of the Kreyenhagen. In the Jergins Oil Co. well, Chaney Ranch No. 1, it is abundant at 4050 feet, and it occurs in the Seaboard Oil Corp. well, Oro Loma No. 1, at 3141 feet and deeper. It is also present in the Seaboard Oil Corp. well, Welch No. 1, at 4220 feet and deeper; and in the Seaboard Oil Corp. well, Gill No. 1, at 4039 feet and deeper. In the Western Gulf Oil Co. well, Lillis Welch No. 1, it occurs from 716 feet downward and is extremely abundant at 1087 feet. The scale is found also in the Refugian stage, and occurs in the Amerada Petroleum Corp. well, Beer No. 1, at depth from 3557 to 3567 feet, and more frequently in the Eocene at depth from 3927 to 4080 feet. In the Texas Co. well, Pioneer Unit Plan No. 1, the scale occurs at a depth of 8021 feet and deeper; in the Pioneer Unit Plan No. 2, at a depth of 9212 feet.

Relationships. Parapolymixia has the characters of the specialized scales of the Polymixiidae. The Eocene genus shows the characteristic basal folds, arrangement of circuli, and position of nucleus of the Recent genus *Polymixia.* The fossil species described here has smaller scales and of more regular shape than in *Polymixia;* they usually present only one row of spines, whereas a number of rows of spines are present in the modern genus. The Polymixiidae are a very specialized group of berycomorph fishes, and are inhabitants of seas of medium depth. *Polymixia* appears to be usually caught in depths from 190 to 350 fathoms, and apparently does not descend to very great depths. The range of the family does not extend beyond the tropical and subtropical zones. *Polymixia* is found in the Caribbean Sea off the West Indies. It is likewise found off Madeira, off the Hawaiian Islands, and off Japan. It has been recorded from Tortugas (Longley and Hildebrand, 1941, p. 52), with 2 specimens from 45 to 60 fathoms and 5 specimens from 140 to 197 fathoms.

Family BERYCIDAE. ALFONSINOS

Beryx san-joaquinensis, n. sp.

(Plate 3, figure 3; plate 4, figure 1; text figure 6*c*)

Type. No. 10328, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.1 mm. long by 3.7 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3570 to 3597 feet. Tumey formation.

Description. Scale coarse, rectangularly oblong to elongately rounded; measurements (in millimeters) of length and depth vary as follows: rectangular scales, 2.9 by 3.9, 3.1 by 2.1, 3.1 by 3.9, 3.1 by 4, 4 by 4.6; rounded scales, 4.1 by 5, 5 by 5.1. Basal part in rectangular scales angular, laterobasal angles well formed; dorsal and ventral sides curved as characteristic of genus, but not strongly concave. Smooth side showing strong angular growth lines, concentric to external margin. Basal pole not folded or weakly folded. Central sector of basal part vertically protruding above remaining part of scale. Nucleus above center; coarse circuli present on basal part above nucleus, irregularly rounded to elongate, widely spaced, 22 in 1 mm.

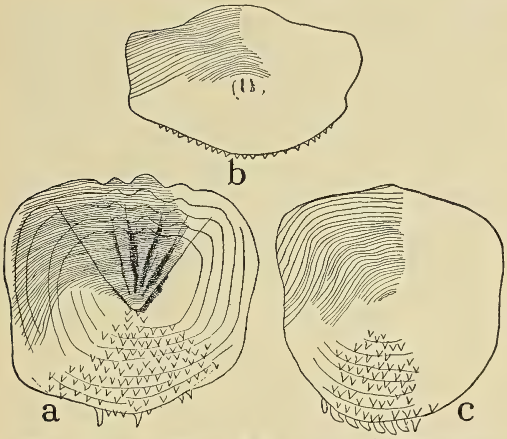

FIG. 6. *a, b, Beryx ḳcli,* n. sp. (*a*) Diagram after type, no. 10329 C.I.T. Scale 4.1 mm. long by 4 mm. deep. Richfield Oil Corp. well, K.C.L. No. 1. (*b*) Scale 3.2 mm. long by 4.1 mm. deep. Richfield Oil Corp. well, K.C.L. No. 1. Zemorrian stage.

c, Beryx san-joaquinensis, n. sp. Type, no. 10328 C.I.T. Scale 4.1 mm. long by 3.7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

All × 8.

distance. Laterobasal angle rounded, circuli abruptly bent outward above the laterobasal diagonal and ending in dorsal and ventral margins. Part of scale below nucleus smooth. Apical region has scattered spines which are usually lost with actual scale, but are indicated by cavities or by corresponding elevations when only mold of smooth side is present. Some spines indistinctly visible at apical margin. Elongately rounded scales (pl. 3, fig. 3) are probably atypical scales of same form: basal part strongly elevated, circuli rounded, occupying upper two-thirds of scale, leaving a triangular sector of apical pole smooth. Growth lines well marked in basal part.

Occurrence. The scale has been found abundantly in the Jergins Oil Co. well, Chaney Ranch No. 1, from 3570 to 3597 feet and also between 3624 and 3647 feet.

Beryx eogenus, n. sp.

(Plate 4, figure 3)

Type. No. 118, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 4.5 mm. long by 5 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth between 3570 and 3597 feet. Tumey formation.

Description. Scale rectangular with more or less deeply concave dorsal and ventral borders, as in *Beryx splendens.* Measurements (in millimeters) of length and depth vary as follows: 4.5 by 5, 4 by 5 (lateral-line scale), 3.1 by 3.5, 1.5 by 2. Few basal folds, if any, projecting as sharp triangles in center of otherwise truncate basal border. Growth lines well marked on smooth side of scale. Central sector of basal part feebly elevated beyond remaining part of scale. Moderately dense transverse circuli present, densest above nucleus, widening toward dorsal and ventral borders. Basolateral angles rounded, not very well defined. Apical part generally smooth, spines restricted to one row at apical border, spines strengthened by apical ridges protruding into apical part of scale.

Occurrence. Scales moderately abundant in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3570 to 3647 feet.

Beryx kcli, n. sp.

(Text figure 6*a, b*)

Type. No. 10329, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.1 mm. long by 4 mm. deep.

Type locality. Richfield Oil Co. well, K.C.L. No. 1, at depth from 6443 to 6452 feet. Zemorrian stage.

Description. The Lower Miocene form is described here in order to give more detailed information concerning the generic characters and for comparison with the Eocene forms, which are as yet little known. Scale rather small, rectangular in shape; measurements (in millimeters) of length and depth vary as follows: 4 by 5, 4 by 4, 3 by 3.5, 3 by 2.8, 1 by 1.9. Deeper scales (fig. 6*b*) (3 by 4 mm.) found occasionally, probably atypical scales of the same form. Basal pole generally with a number of strong undulations at its center, folds projecting as sharp triangles beyond an otherwise truncate basal border. Apical pole rounded; pronounced concentric growth lines visible in basal and apical regions. Growth lines in basal part dividing folds or undulations into a number of sections, which form characteristic pattern on central basal sector of scale, and are especially clear on mold of smooth side. Dorsal and ventral margins concave. Central sector of basal part vertically elevated above remaining part of scale. Dense transverse circuli present in basal part (36 in 1 mm. distance), more or less straight in center, not following undulations and growth lines. Central circuli very short, rapidly increasing in length toward basal border, bending apicad in laterobasal diagonal, apical ends of circuli more widely spaced. Spines irregularly distributed over apical part, spines preserved only when scale itself is present; in impressions of scales, spines are indicated by triangular cavities with elevated margins. Rather strong spines indicated in some specimens along apical border. Rectangular scales (fig. 6*b*) with central nucleus; circuli transverse in basal region, short in center and rapidly increasing in length; one row of spines evidently present along apical margin, otherwise smooth.

Occurrence. This scale is very abundant in the Zemorrian (Temblor) of the southern San Joaquin Valley, and is found throughout this stage. It is especially abundant in the Richfield Oil Corp. well, K.C.L. No. 1, and in the Union Oil Co. well, Gibson No. 7.

Relationships. The three fossil species described above are nearly related and are probably identical with the very distinctive scale of the genus *Beryx*. Of the Eogene forms, *B. eogenus* comes nearer to the scale of the Recent genus than does the coarser scale of *B. san-joaquinensis,* which may very well represent a different genus. The Miocene species *B. kcli* approaches the modern scale most closely, and description of this abundantly occurring species seems advisable, to facilitate recognition of the generic characters in these fossil scales. The scales of the genus are evidently very brittle, and are lost in most instances. If the scale is preserved, the coarse side is attached to the rock, and the spines are visible only through the scale. Spines in *Beryx* are irregularly scattered over the apical part, being often broken and turned upward vertically. Their position is indicated in the drawings by triangles, since it was not possible to draw the actual shape, which is only indistinctly seen through the scale. *Beryx kcli* has small scales in which the depth is not quite so great as in Recent *Beryx*. Dorsal and ventral margins are concave, although not so strikingly so as in Recent species and as in some of the known Cretaceous forms. The central sector of the basal region is strongly raised vertically, and basal and apical parts are divided by a groove which is typical of the genus. Spines, inserted in triangular cavities, are scattered over the apical region in the Miocene and Recent forms. Spines are less numerous in the Eogene forms and may be restricted to one row in some of the scales. Circuli are restricted to the basal part and show the same pattern in *B. kcli* and *B. eogenus* as in modern scales of the genus. They are coarser and more rounded in *B. san-joaquinensis.* The Miocene species shows strong undulations in the basal part, whereas in *B. splendens* only weak folds, if any, are present. In *B. eogenus* a few less pronounced folds are present; none is developed in *B. san-joaquinensis.* The basal undulations, where present, together with the marked growth lines give a characteristic pattern of irregular triangular elevations to the fossil scale, which make it easily recognizable.

Beryx san-joaquinensis is readily distinguished from the two other species by the very coarse circuli, the absence of folds in the basal part, and the different shape of the scales. *Beryx eogenus* is larger than *B. kcli* and has slightly coarser circuli and fewer basal folds; apical spines are less numerous and the row of spines along the apical border is stronger.

Beryx is a cosmopolitan genus of the warm open seas. Species are known from moderate depth (424 fathoms), and others occur in rather deep water. The genus is known off Madeira and Cuba, in the Gulf Stream, and off Japan and Australia. There seems to be no record from the eastern Pacific Ocean.

The actual range of the fossil species is difficult to determine. *Beryx kcli* is very abundant in the Lower Miocene of the southern San Joaquin Valley. It may well have become extinct by Middle Miocene time. The Eogene *B. san-joaquinensis* shows more primitive characters, indicated by its coarser pattern. It may be restricted to the Eocene. *Beryx eogenus* is related to the Miocene and to modern forms.

ORDER PERCOMORPHI

SUBORDER PERCOIDEA PERCIFORMES

Family MORONIDAE. WHITE PERCHES

Paramorone eocenica, n. g. and n. sp.

(Plate 3, figure 5; text figure 7*a, b*)

Type. No. 10317, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5.5 mm. long by 5 mm. deep.

Cotype. No. 10319, Calif. Inst. Tech. Vert. Pale. Coll. Scale 3 mm. long by 3 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3624 to 3647 feet. Tumey formation.

Description. Type specimen is a well preserved scale from lateral part of fish; external border of apical pole missing, this part being seldom present in fossil percomorph scales. Cotype is a scale from anterodorsal part of fish. Lateral scales quadrangular, slightly longer than deep in type. Basal part divided into folds of subequal size (7 in type); most central folds extending from basal border to nucleus. Basal border almost straight, very little scalloped in region of folds. Nucleus subapical, surrounded by 3 or 4 concentric circuli, forming a sharp angle toward the

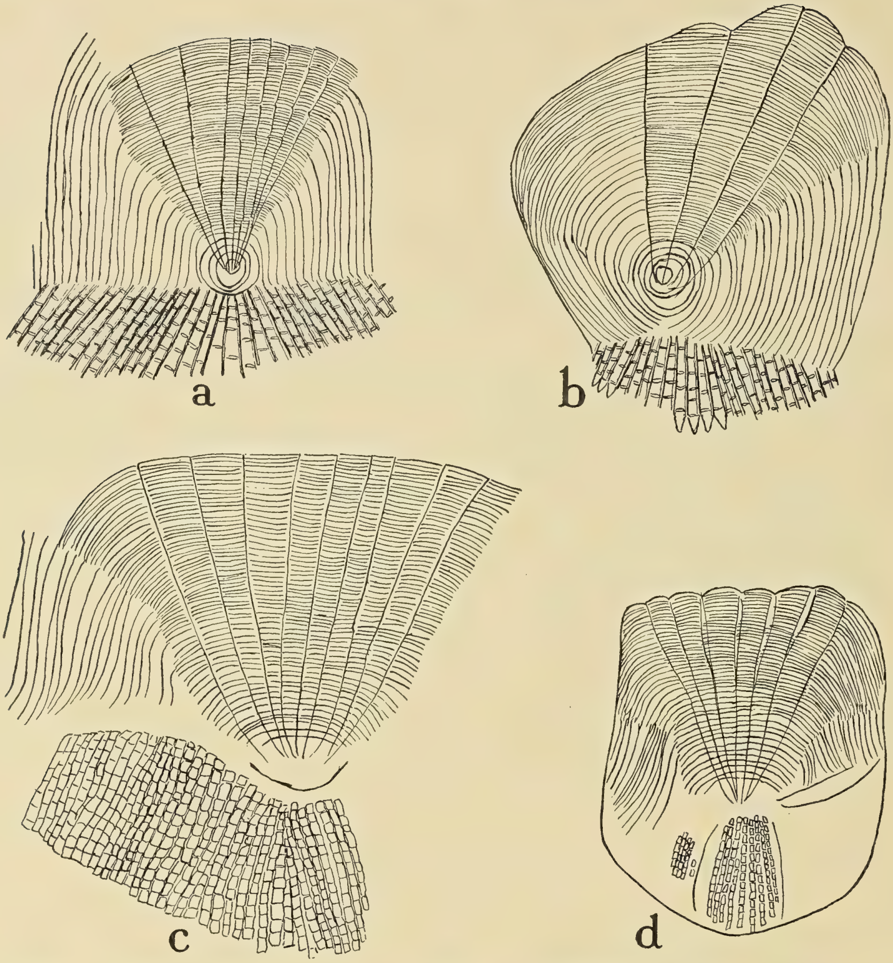

FIG. 7. *a, b, Paramorone eocenica,* n. g. and n. sp. (*a*) Nuclear center of type, no. 10317 C.I.T. Jergins Oil Co. well, Chaney Ranch No. 1. (*b*) Cotype, no. 10319 C.I.T. Scale 3 mm. long by 3 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation. × 20.

c, d, Kreyenhagenius joaquinensis, n. g. and n. sp. (*c*) Nuclear center of type, no. 10318 C.I.T. Seaboard Oil Corp. well, Gill No. 1. (*d*) Cotype, no. 10320 C.I.T. Scale 3 mm. long by 2 mm. deep. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation. × 20.

apical end of the scale. Circuli in dorsal and ventral triangle of basal part coarse, almost straight, 21 or 22 in 1 mm. in nuclear region. Circuli in central basal sector much finer, almost twice as numerous, divided into small sections by folds, 31 in 1 mm. distance at basal border of scale. Central circuli form rounded and wide latero-basal angles along diagonals of scales, beyond which they end between or continue into the coarser circuli of the dorsal and ventral sectors. Apical pole divided from basal part by an almost straight line. Apical part divided into numerous comparatively coarse, vertically projecting radii, 17 or 18 in 1 mm. distance below nucleus. Radii more or less straight, showing little ornamentation, subdivided into rectangular, rodlike elements, longer than broad. Spines present only in cotype, stout, little longer than broad. Scale folded many times, in regular intervals parallel to borders of basal part. These folds do not correspond to annular rings; type scale probably 3 to 4 years old. Cotype with asymmetric shape and reduced number of folds typical for scales of anterodorsal body region in this group of fishes, otherwise showing characters of species.

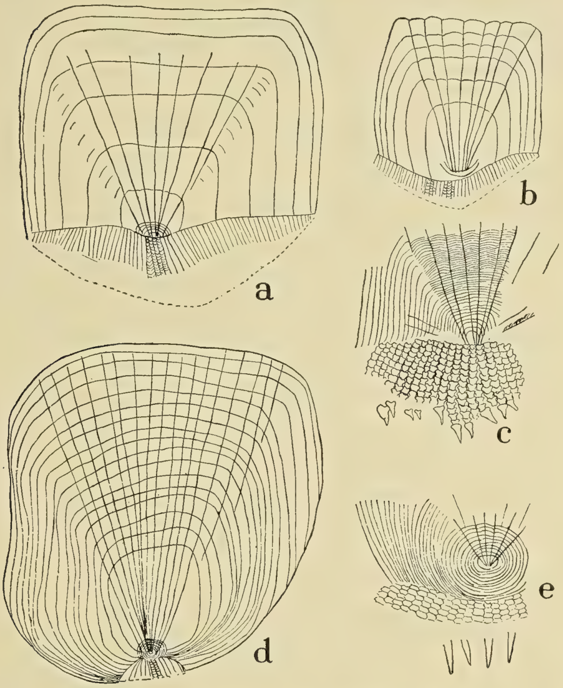

Fig. 8. *a, c, Lompoquia* cf. *culveri* (Jordan). (*a*) Diagram of scale from Mulholland Highway, Santa Monica Mts., Middle Mohnian. × 10. (*c*) Nuclear center of scale from Mulholland Highway, Santa Monica Mts., Middle Mohnian. × 20.

b, Lompoquia cf. *retropes* Jordan and Gilbert, from Axis Oil Co. well, Rowland No. 1, Delmontian stage, Upper Miocene. × 10.

d, e, Cynoscion cf. *eprepes* (Jordan). (*d*) Diagram of scale from Petroleum Securities Oil Co. well, Burbank No. 1, McLure shale, Upper Miocene, Upper Mohnian. × 10. (*e*) Nuclear center of scale from Petroleum Securities Oil Co. well, Burbank No. 1. × 20.

Occurrence. Type and cotype come from the Jergins Oil Co. well, Chaney Ranch No. 1, where the scale occurs down to 4404 feet. The scale has been found elsewhere in the Kreyenhagen, and is probably not rare at shallower depths of the Upper Eocene and Oligocene.

Relationships. The scale as compared with the majority of Recent percomorph scales is characterized by coarseness of structure, especially in the nuclear region. In general, greater coarseness can be considered as a primitive character. Ornamentation of the apical radii also is little developed, and the radii appear as almost straight lines vertically projected. A somewhat similar structure prevails in the living genus *Morone,* especially in the European species *Morone labrax* (see Meek, 1916, pl. 10). The nuclear structure in *Morone* is less coarse, however, and the basal radii are not directed straight toward the apical pole, but are bent toward the nucleus. *Paramorone* can be considered a distant relative of the existing Moronidae. This family lives today along the borders of the ocean, frequently entering brackish water and rivers. It is sometimes confined to fresh water. The genus *Morone* in America is restricted to the Atlantic border of the continent. The Moronidae occupy a temperate to tropical habitat. The Eocene form did not necessarily have the same habitat, as it is only distantly related to modern forms. Percomorph fishes came into existence at the end of the Cretaceous and developed rapidly throughout the Tertiary. The developmental changes probably involved changes in environment as well. Presumably the Eocene *Paramorone* lived in coastal waters; it is doubtful whether it entered fresh water.

In the Upper Miocene of California two sciaenid genera, *Lompoquia* and *Cynoscion,* present the most abundant spiny-rayed fishes. The nuclear structure in these genera is considerably finer than in *Paramorone,* and the apical features are more advanced. Figure 8 shows these forms for comparison.

Family DENTICIDAE. Dogs-teeth

Kreyenhagenius joaquinensis, n. g. and n. sp.

(Plate 3, figure 4; text figure 7*c, d*)

Type. No. 10318, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5 mm. long by 5.8 mm. deep.

Type locality. Seaboard Oil Corp. well, Gill No. 1, at depth of 4051 feet. Kreyenhagen formation.

Cotype. No. 10320, Calif. Inst. Tech. Vert. Pale. Coll. Scale 3 mm. long by 2 mm. deep. Specimen from Seaboard Oil Corp. well, Oro Loma No. 1, at depth from 3220 to 3229 feet. Kreyenhagen formation.

Description. Lateral scales rounded to fan-shaped, deeper than long; type well preserved, ends of apical radii missing. Apical part large, measuring one-third length of scale in type. Cotype a small scale as found in dorsal and ventral extremities of body in these fishes. Basal region divided into a number of folds, 9 in type, their basal border extending along entire scale, all folds originating in nucleus, forming a typical fan. Basal border weakly scalloped, basal ends of folds projecting in rounded curves. Nucleus subapical, divided by a smooth groove from apical region. Nucleus marked by circuli overlying it horizontally, these slightly rounded, increasing rapidly in width, most central ones coarsest. Circuli become fine toward basal border. Horizontal circuli form wide, rounded angles along diagonals of basal region, their ends directed toward dorsal and ventral borders of scale in its anterior two-thirds. Central circuli divided by folds; 31 circuli in 1 mm. distance starting with lowest horizontal one, 48 in 1 mm. distance at basal border. Circuli in dorsal and ventral basal sections of scale that are free from folds are farther apart, but feeble, and of varying length, their ends curved outward, directed toward dorsal and ventral borders of scale. About 24 circuli in 1 mm. distance in sections dorsal and ventral to the nucleus. Groove dividing nucleus from apical region wide and well marked. Circuli seemingly not continued beyond groove and around nucleus. Apical region divided from basal part by a subtriangular space with lowest point in center. Apical region divided into numerous radii, 24 in 1 mm. distance in center. Radii flat, strongly projected vertically, subdivided into a number of quadrangles with their dorsal and ventral sides rounded to angular. Radii not always developed in atypical scales, or not occupying entire apical region, as shown in cotype. Folding of scale around outer margin not very apparent.

Occurrence. This scale was found in the Kreyenhagen of the Seaboard Oil Corp. well, Gill No. 1, and in the same formation penetrated by the Oro Loma well No. 1. It also occurs in the Jergins Oil Co. well, Chaney Ranch No. 1, at a depth of 4330 feet and deeper. It is evidently an Upper Eocene scale characteristic of shallow-water deposits. It is rare everywhere in the Kreyenhagen shale where it has been found.[2]

Relationships. The scale shows no particular resemblance to that of any known living form, but seems to be distantly related to the Denticidae. *Kreyenhagenius* has the fan-shaped structure of the scales seen in some members of this family. It differs in that its outline is rounded, the ends of the folds project less beyond the basal margin, and the folds do not have pointed ends. The nuclear structure, character of the folds, and central circuli resemble comparable features seen in the Denticidae, but the dorsal and ventral circuli, although bent at their ends, do not show the typical rounded outward curvature of these structures in the Denticidae and in the related Sparidae. Moreover, the dorsal and ventral circuli are farther apart. *Kreyenhagenius* was probably related to the Denticidae or to the primitive Sparidae, and may represent an ancestral type featured by the shape of the scale and by the structure of dorsal and ventral circuli. *Dentex* has been found in Upper Eocene marine sediments of Europe, and related forms should be expected in corresponding deposits of America. The Denticidae are essentially inhabitants of warm climates. Typical sparid scales are represented in the Miocene of California by *Plectrites* and *Rhythmias* (see David, 1943, p. 28, fig. 66; 1944, pl. 5, fig. 50).

Family ? CHILODIPTERIDAE

Praegaleagra pupensis, n. g. and n. sp.

(Text figure 9)

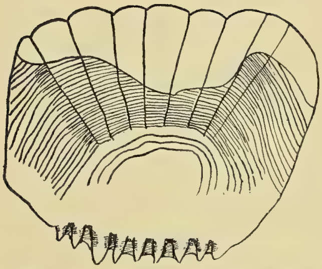

FIG. 9. *Praegaleagra pupensis,* n. g. and n. sp. Type, no. 10332 C.I.T. Scale 2.6 mm. long by 3 mm. deep. Texas Co. well, Pioneer Unit Plan No. 2. Kreyenhagen formation. × 32.

Type. No. 10332, Calif. Inst. Tech. Vert. Pale. Coll. Scale 2.6 mm. long by 3 mm. deep.

Type locality. Upper Eocene deposits of Texas Co. well, Pioneer Unit Plan No. 2, at depth between 9700 and 9707 feet. Kreyenhagen formation.

Description. Only regenerated scales present, these slightly deeper than long. Approximately 7 subequal folds in basal part, basal margin scalloped, edges of folds rounded; basal radii strong, sectioning circuli, not continued into regenerated part. Circuli more or less concentric with margin of basal part of scale, curved in region of folds and continuing around laterobasal angles, the latter being rounded; dorsal and ventral sectors of basal part with less crowded, irregular circuli, in part ending in dorsal and ventral margins, in part toward apical portion, circuli probably more regular in an original not regenerated scale. Nucleus evidently subapical. Apical pole smooth, without circuli or ctenoid structures, equipped with one row of irregular simple strong spines, projecting vertically in subapical marginal field, incompletely preserved.

Only the type and cotype of this form are known.

Relationships. It seems difficult to place the small scale that shows the basal structure of perciform fishes and an apical pole simply equipped with a row of strong vertically projecting spines. Somewhat similar scales are found in certain deep-sea percomorph fishes, as *Galeagra, Bathysphyraenops,* and others. All these genera are attributed to the Chilodipteridae, and *Praegaleagra* is tentatively placed in the same family. It differs from related genera in the structure and crowded nature of the circuli. The scales of *Galeagra* are much smaller than those in the fossil form; other related genera have larger scales. Although the small fossil form is not well known, its particular features are sufficiently characteristic to permit a recognition of its relationships.

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[2] This type of scale has been found to be extremely abundant in the shallow-water deposits of the Middle Eocene Llajas formation of Simi Valley.

Suborder PERCOIDEA CARANGIFORMES

Family CARANGIDAE. Jacks

Caranx orolomaensis, n. sp.

(Plate 1, figures 2, 3)

Type. No. 10330 Calif. Inst. Tech. Vert. Pale. Coll. Scale 1.8 mm. long by 2 mm. deep.

Type locality. Seaboard Oil Corp. well, Oro Loma No. 1, at depth from 3141 to 3170 feet. Kreyenhagen formation.

Description. Scales small, ovoid; typical measurements (in millimeters) of length and depth are 1 by 1.2, 2 by 2; elongate scales that measure 4 by 2 mm. are rare. Simple, degenerate scales with central nucleus; circuli irregularly rounded, concentric, irregularly angular but not symmetrical on both sides of mediolateral diagonal. Occasionally present are elongate scales with pointed apical pole. Circuli coarser at one side, probably basal region, 38 to 42 in 1 mm. distance, more numerous at other side, 54 to 58 in 1 mm. distance. In larger, elongate scale, 44 circuli in 1 mm. distance.

Occurrence. This scale is not rare in the Kreyenhagen of the Seaboard Oil Corp. well, Oro Loma No. 1, at depth from 3141 to 3242 feet. It also occurs in the Kreyenhagen of the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 1579 to 1605 feet, and in the Jergins Oil Co. well, Chaney Ranch No. 1, from 4304 to 4330 feet.

Relationships. This small scale is not unlike many of the degenerate scales of the carangids of today, for example *Hemicaranx, Caranx,* some members of *Seriola,* and others. Degenerate scales like the fossil, with irregularly rounded circuli that are more widely spaced at one side and are irregularly angled, are found in some species of the above-mentioned genera, whereas the majority of the carangid forms have distinctly symmetrical scales. The counts of the circuli in the fossil form are nearly comparable to those of living forms, although in the former the circuli appear coarser. The latter appearance may be an optical effect, due to stronger shadows. Scales shaped like that seen in plate 1, figure 2 occur also in Recent fishes with the more typical rounded ones. Definite generic allocation of the type is difficult with only the scale available. It seems best under the circumstances to include it with the common *Caranx.* This form and *Hemicaranx* are inhabitants of warm climates. This type of carangid scale has heretofore not been found fossil in California. It is distinguished from the other known types by its small size and irregularly rounded circuli.

Suborder SCOMBROIDEI

Family SCOMBRIDAE. Mackerels

Eoscombrus chaneyensis, n. g. and n. sp.

(Plate 4, figure 2)

Type. No. 116, Paleontological Laboratory of the Richfield Oil Corporation, Long Beach, California. Scale 3.9 mm. long by 3.5 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 3570 to 3597 feet. Tumey formation.

Description. The small ovoid type is the only scale collected so far. Less well preserved scales with apical and basal borders parallel may belong to this form. Scale simple, radial structure in basal part, fine concentrically rounded circuli in basal part, asymmetrically angular in apical part. 19 (near basal border) to 22 circuli in 1 mm. distance. Apical part divided into numerous apical radii toward apical border, protruding toothlike beyond border. Nucleus central, wide, probably regenerated, ornamented with indistinct tuberculations.

Relationships. The type scale shows the very typical characters of the Scombridae, with the asymmetrically angular, concentric circuli and the apical radii. As a whole, the scale is much coarser than those of the Recent mackerel.

Faunal Assemblages and Zoning of Sections

Table 1 gives a list of all the species of fish found in the Upper Eocene of the San Joaquin Valley. The abundance of individual kinds is given, as based upon the frequency of their occurrence in the entire Upper Eocene section of the valley. The nearest living relatives of the fossils are indicated, as well as the presence or absence of the families and genera in the Miocene.

The different kinds of fossil fish listed in the table are not equally distributed throughout the stratigraphic succession, and several subdivisions are therefore distinguishable. Two of these units can be readily recognized in a number of the subsurface sections, whereas in others only the lower one of the two is present. Furthermore, two zones may be determined within the latter. The first one of these may be subdivided in some cases. The chart, figure 10, attempts to establish a correlation between the occurrences of the fossil material of Kreyenhagen age, and shows the frequency of occurrence of the more abundant forms. It should be remembered that only a limited number of samples are available for scale study from most of the wells, and this limitation is responsible for the gaps in the sequence of samples shown in the chart. The information concerning fossil scales thus far obtained from the Kreyenhagen is incomplete. It seems entirely possible that more information can be obtained from some of the wells. In the Seaboard Oil Corp. well, Oro Loma No. 1, and in the Seaboard Oil Corp. Gill and Welch wells only the core samples indicated in the chart were available for study, although considerable coring was actually done.

No fossil scales were collected by the writer in surface outcrops of the Kreyenhagen formation. However, material made available from the Kreyenhagen of

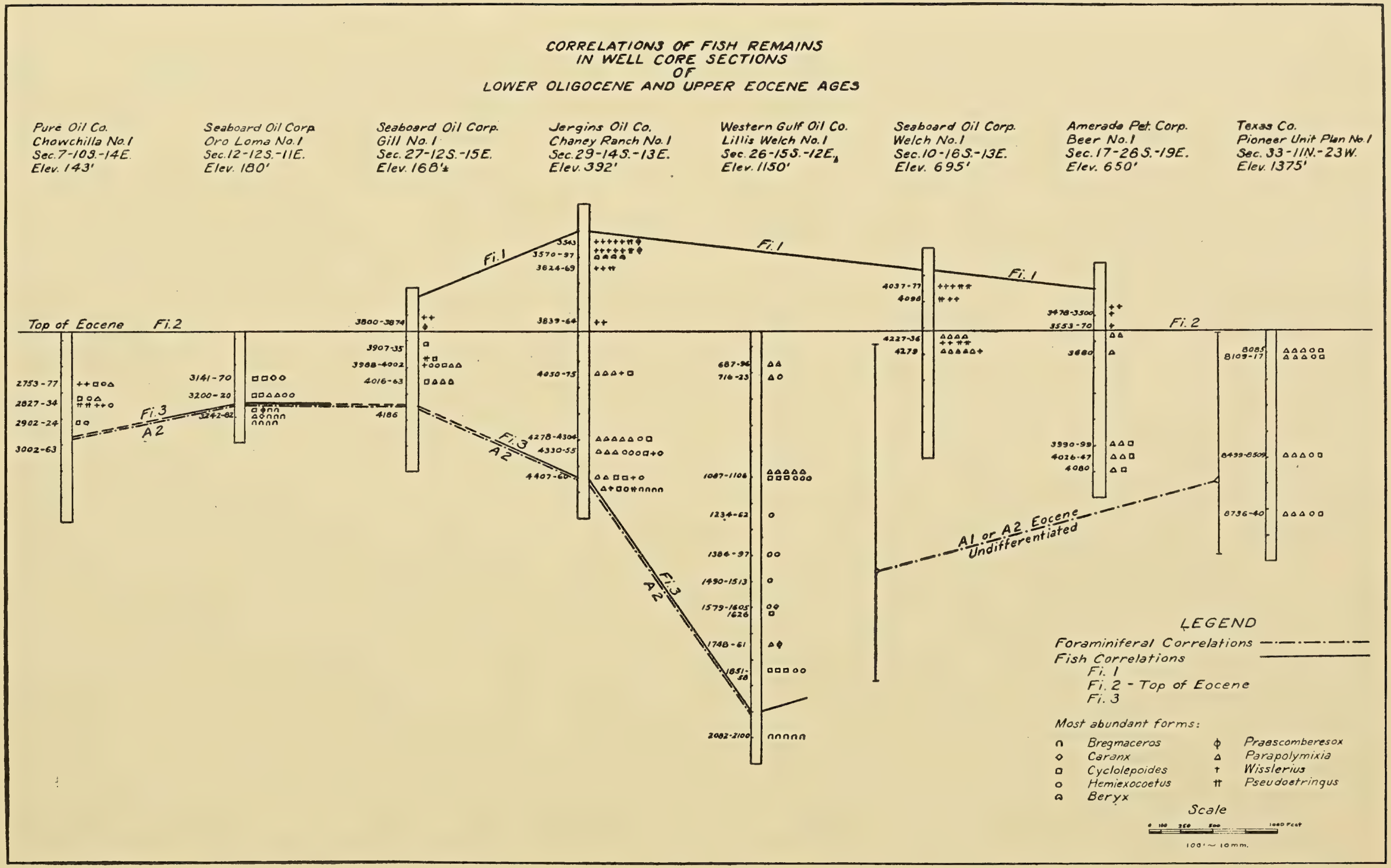

FIG. 10. Correlation of fish remains in well-core sections of Lower Oligocene and Upper Eocene ages, San Joaquin Valley, California

the North Coalinga district (Cantua–Salt Creek–Domengine region), Fresno County, corresponds well to that determined in the well cores. Zones Fi 1 and Fi 2 are well represented.

TABLE 1

List of families, genera, and species of fishes from Lower Oligocene and Upper Eocene deposits, San Joaquin Valley, California

Family, genus, and species	Relative abundance*	Occurrence in California		Nearest living relative
		Miocene	Mio-Oligocene	
Carchariidae	....	+	+	
Galeocerdo? sp.	R	..	..	Galeocerdo
Dussumieridae	....	+	+	
Pseudoetringus kreyenhagius	A	..	..	?
Clupeidae	....	+	+	
Wisslerius sardinelloides	A	..	..	Sardinella
? Alosa ganolytoides	R	..	..	Alosa?
Coregonidae	....	?	+	
Parastenodus gillensis	R	..	..	Stenodus
Beckius plicatus	R	..	..	Leucichthys?
Cyclolepidae	....	..	+	
Cyclolepoides tuberculatus	AA	..	+	?
? Chlorophthalmidae	....	..	..	
Iniomus fossilis	R	..	..	Chlorophthalmus?
? Scomberesocidae	....	+	+	
Praescomberesox pacificus	M	..	..	Scomberesox?
Hemiramphidae	....	+	+	
Hemiexocoetus eocenicus	AA	..	..	Evolantia
Bregmacerotidae	....	..	..	
Bregmaceros kreyenhagus	A	..	..	Bregmaceros
Polymixiidae	....	..	..	
Parapolymixia californica	AAA	..	..	Polymixia
Berycidae	....	..	+	
Beryx san-joaquinensis	AM	..	+	Beryx
Beryx eogenus	M	..	+	
Moronidae	....	..	..	
Paramorone eocenica	M	..	..	Morone
Denticidae	....	..	?	
Kreyenhagenius joaquinensis	M	..	?	Dentex
? Chilodipteridae	....	..	..	
Praegaleagra pupensis	R	..	..	Galeagra?
Carangidae	....	+	+	
Caranx orolomaensis	M	..	?	Caranx
Scombridae	....	+	+	
Eoscombrus chaneyensis	R	..	..	Scomber

*R, rare; M, moderately represented; A, abundant; AA, very abundant; AAA, extremely abundant.

Three distinct fish-scale assemblages are recognized as a result of the studies of the well-core samples. In the stratigraphic sequence from top to bottom these are designated Fi 1, Fi 2 (or Fi 2*a* and Fi 2*b*), and Fi 3. They are described individually as follows:

Assemblage Fi 1

The upper assemblage is of Oligocene age and is characterized by an abundance of the clupeoid fishes *Pseudoetringus* and *Wisslerius*. Either form may occur in abundance; sometimes both are found, sometimes only one. *Praescomberesox* and *Cyclolepoides* are present, and *Paramorone* may be characteristic. Other types are occasionally present. This assemblage is clearly represented in the uppermost Kreyenhagen of the Jergins Oil Co. well, Chaney Ranch No. 1, where *Wisslerius* abounds. Here berycid fishes are also very abundant. These strata correspond to the so-called Leda zone. In the Seaboard Welch well at a depth from 4000 to 4100 feet clupeoid fishes are well represented. The Salt Creek section also shows this assemblage clearly; in its upper 200 or 300 feet *Pseudoetringus* is by far the most abundant fossil. *Wisslerius, Paramorone,* and *Hemiexocoetus* ? occur. In the Seaboard Gill well the zone is less clearly marked, from 3800 to 3900 feet. In the Pure Oil Co. Chowchilla well the evidence is not clear.

Assemblage Fi 2

The top of Fi 2 is marked by a great abundance or dominance of *Parapolymixia.* In certain strata this form is the only fish fossil present, and it may occur repeatedly, as in the Texas Co. well, Pioneer Unit Plan No. 1. In other horizons *Hemiexocoetus* and *Cyclolepoides* are found associated with *Parapolymixia,* and either one of the former may be fairly abundant. The three genera are the most abundant types; other forms may appear, but never in significant numbers. Fi 2 is the most characteristic assemblage of the Kreyenhagen wherever this formation occurs. The position is clearly indicated in the wells shown in figure 10. The characteristic scales of this assemblage occur in some wells in a stratigraphic sequence of considerable thickness. That part of the assemblage which is featured by a dominance of *Parapolymixia* appears to correspond to the top of the zone (Fi 2*a*) and of all strata of Eocene age. It is underlain by strata in which the occurrence and frequency of the three principal forms varies, and *Parapolymixia* is not necessarily present (Fi 2*b*). In the Salt Creek section Fi 2 is found in the lower part of the stratigraphic succession within a thickness of 150 feet or more.

Assemblage Fi 3

In a number of wells faunal changes, indicated by the fossil fish scales, are noticeable in the samples from the lowest Kreyenhagen. Abundant specimens of *Bregmaceros* were found in these wells. This fish has not been observed in higher horizons. *Caranx* is also moderately abundant at this stage, but not higher. *Kreyenhagenius* occurs, and *Cyclolepoides, Praescomberesox,* and *Hemiexocoetus* are present in moderate numbers.

The zoning attempted above is based on a limited number of samples. It will probably undergo change and refinement with the acquisition of further information. The distinction between Fi 1 and Fi 2 appears to be clearly established in all sections where both assemblages occur. Fi 2*a*, Fi 2*b*, and Fi 3 cannot be readily differentiated in all sections.

ECOLOGIC SIGNIFICANCE OF KREYENHAGEN FISH SCALES

Bathymetric Conditions

The fossil fish-scale assemblages found at different horizons of the Kreyenhagen formation reflect the presence of varying bathymetric conditions. Slight changes in the environment furnish a plausible explanation for the sequence of scale assemblages in the Upper Eogene. Fi 1 was deposited in a neritic environment. In support of this view may be cited an abundance of herrings, presence of percomorph fishes as well as Synentognathi and *Beryx*, and the rare occurrence of an Iniomi. A deep neritic habitat appears to be the most likely place of accumulation for this faunule. Doubtless a much greater variety of types will be found when the assemblage is better known.

In the larger part of the Kreyenhagen shale occurs Fi 2, which furnishes a very peculiar and interesting assemblage. Three genera are represented in the main: *Parapolymixia*, a scale very much like that of the living barbudo; *Hemiexocoetus*, a primitive flying fish; and *Cyclolepoides*, related to the salmons. These are the most characteristic Upper Eocene scales from the San Joaquin Valley, and they are found in all well cores taken from the Kreyenhagen formation. It appears likely that they are characteristic of other Upper Eocene deposits in California. A few similar scales are known from the Kellogg shale of the Mount Diablo region. A bathypelagic environment of medium depth is a likely place for a common occurrence of these three forms in such large numbers, generally unaccompanied by other types. The Hemiramphidae and the Exocoetidae, to which families *Hemiexocoetus* shows relationship, are pelagic, with members living in either neritic or oceanic environments. Some of these fishes swim far out in the ocean. *Cyclolepoides* is a salmonoid fish of unknown relationships. Its habitat is difficult to determine. It is known, however, that feeding salmon of today frequent the water of the open ocean, as well as that adjacent to the coast. Both forms therefore might be expected far out in the open sea, beyond the province inhabited by the majority of neritic fish. Furthermore, oceanic currents may transport to sea the scales held in suspension, their final resting place depending on the rate of settling of such scales. The most diagnostic scale is that of *Parapolymixia*, which occurs abundantly and with regularity. *Polymixia*, although occasionally caught nearer shore, is essentially a fish of medium depths (150 to 350 fathoms) and evidently does not descend to greater depths. A bathymetric zone of medium depth was apparently the scene of accumulation of the principal assemblage from the Kreyenhagen. It represents an environment in the depth of the oceanic province beyond reach of neritic forms. Deposition did not occur at greater depth, however, and probably a depth beyond 400 fathoms was not reached. The Kreyenhagen formation is considered to have accumulated in a marine trough of north-south extension. The sediments in which the Fi 2 scale assemblage occurs may well have been deposited in the central and deepest part of such a large marine province.

Fi 3 is recognized in a few thin sections at the base of the stratigraphic column. This assemblage shows an increase in variety of forms. The strata continue farther down as sandy or silty beds which are barren or in which the scales are poorly represented. This assemblage was deposited in shallower water than that in which Fi 2 accumulated. It still represents, however, a bathypelagic habitat, as is shown by the abundance of *Bregmaceros*.

Temperature

All the families and genera found in the Kreyenhagen and still existing today live principally in tropical seas, although some are also represented in temperate waters. There are no forms present that are restricted to temperate water, but a number of genera are known only from warm seas, for example, *Galeocerdo, Bregmaceros, Polymixia,* and *Caranx*. The evidence thus strongly suggests that a warm climate prevailed at the time of the Kreyenhagen deposition.

Comparison with California Fossil Fish Assemblages of Post-Eocene Age

Of the 16 families found thus far in the California Eogene, 10 are known from the Miocene (see table 1). Of the 18 genera, only 3 are found in the Miocene, and these occur only in the lowermost formations of that epoch or in the Mio-Oligocene. None of the genera is known from Californian deposits of an age older than Eocene or younger than Miocene. The Oligocene fauna is little known, but is likely to show similarity to that of the Eocene. The differences that exist between the Eocene and Miocene fish faunas are probably due in large measure to difference in temperature. Differences in geographic location of the majority of the Eocene deposits must likewise be considered in accounting for the faunal changes which ensued with the coming of Miocene time.

Correlation of Fish Scales and Foraminifera

On the basis of foraminifers, Laiming (1941) divided the Kreyenhagen into three zones, A1 to A3 inclusive. According to him: "A1 is characterized by the common occurrence of *Plectofondicularia jenkinsii* restricted to this zone, and associated with *Planularia markleyana, Eponides pygmaea,* and *Robulus welchi.*" Furthermore: "A2 is characterized by the restricted occurrence of *Uvigerina churchi* associated with *Uvigerina garzaensis, Bulimina corrugata, Gyroidinia orbicularis* var. *planata,* and *Plectofrondicularia packardi.*" Additional foraminifera are recorded from the lower part of A2. Zone A3 is recognized in only a few sections, and none of these is included in the material studied for the present report.[3]

The relation of the horizons containing the fish-scale assemblages to the foraminiferal zones appears to be as follows: The principal part of the section in which fish scales are preserved (Fi 2) corresponds either to zone A1 or undifferentiated A1 and A2, but is younger than typical A2. Fish assemblage Fi 3, in so far as it is present and determinable, may correspond to A2. Quite often, however, A2 is situated in the lower part of the section, in which fish scales are not present or are at best poorly preserved. *Bregmaceros,* a fish characteristic of Fi 3, has one of the smallest known types of fish scale and may be readily overlooked. At other localities in the Kreyenhagen, fish scales occur higher in the section than the established foraminiferal zones, and the foraminifera are sparsely represented. That part of the section in which fish-scale assemblage Fi 1 occurs is considered by students of foraminifers as representing the Tumey formation, of Lowermost Oligocene age.[4]

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[3] Information concerning foraminiferal zones furnished by Boris Laiming in letter dated May 19, 1943.

BIBLIOGRAPHY

BREDER, C. M., JR. 1938. A contribution to the life histories of Atlantic flying fishes. Bull. Bingham Oceanog. Coll., vol. 6, art. 5, pp. 1–126.

COCKERELL, T. D. A. 1919. Some American Cretaceous fish scales with notes on the classification and distribution of Cretaceous fishes. U. S. Geol. Surv. Prof. Paper 120, pp. 165–188.

DAVID, L. R. 1943. Miocene fishes of southern California. Geol. Soc. Amer. Spec. Pub. 43, pp. 1–193.

——— 1944. Use of fossil fish scales in micropaleontology. Carnegie Inst. Wash. Pub. 551, III, pp. 25–43.

DAVIDSON, FREDERICK A., and SAMUEL J. HUTCHINSON. 1938. The geographic distribution and environmental limitations of the Pacific salmon. Bull. U. S. Bur. Fisheries, vol. 48, no. 26, pp. 667–692.

ESTORFF, FRITZ. 1930. The Kreyenhagen shale at the type locality. Bull. Amer. Assoc. Petrol. Geologists, vol. 14, pp. 1321–1336.

JENKINS, OLAF P. 1931. The stratigraphic significance of the Kreyenhagen shale in California. Calif. State Min. Bur., 27th Ann. Rept. State Mineralogist, pp. 141–149.

LAIMING, BORIS. 1941. Eocene foraminiferal correlations in California. State of Calif. Dept. Nat. Resources, Div. Mines Bull. 118, pt. 2, pp. 193–198.

LONGLEY, W. H., and S. F. HILDEBRAND. 1941. Systematic catalogue of the fishes of Tortugas, Florida. Carnegie Inst. Wash. Pub. 535, Papers from Tortugas Lab., vol. 34.

MEEK, ALEXANDER. 1916. The migrations of fishes. London, Edward Arnold.

MURRAY, JOHN, and JOHAN HJORT. 1912. The depth of the ocean. London, Macmillan and Co.

PEABODY, ELIZABETH B. 1931. Scales of fishes of the order Anacanthini. Univ. Colo. Stud., vol. 18, no. 3, pp. 133–150.

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[4] Oral communication from R. Stanley Beck.

PLATES

PLATE 1

EOCENE SCALES, SAN JOAQUIN VALLEY, CALIFORNIA

FIG. 1. *Iniomus fossilis,* n. g. and n. sp. Type, no. 10333 C.I.T. Scale 4.1 mm. long by 4 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

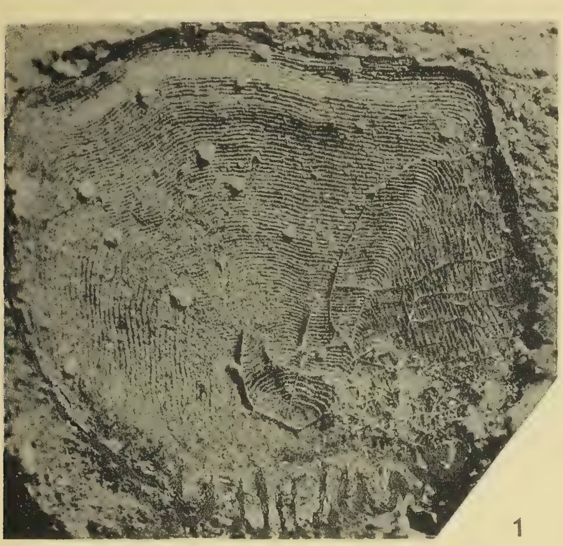
FIG. 2. *Caranx orolomaensis,* n. sp. Elongate scale 4 mm. long by 2 mm. deep. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation.

FIG. 3. *Caranx orolomaensis,* n. sp. Type, no. 10330 C.I.T. Scale 1.8 mm. long by 2 mm. deep. Seaboard Oil Corp. well, Oro Loma No. 1. Kreyenhagen formation.

FIG. 4. *Pseudoetringus kreyenhagius,* n. g. and n. sp. Smooth side of scale 5 mm. long by 5.1 mm. deep. Pure Oil Co. well, Chowchilla No. 1. Kreyenhagen formation.

FIG. 5. *Bregmaceros kreyenhagus,* n. sp. Coarse side of scale 2 mm. long by 1.2 mm. deep. Seaboard Oil Co. well, Oro Loma No. 1. Kreyenhagen formation.

FIG. 6. *Parapolymixia californica,* n. g. and n. sp. Type, no. 10323 C.I.T. Smooth side of scale 2.8 mm. long by 3 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1. Kreyenhagen formation.



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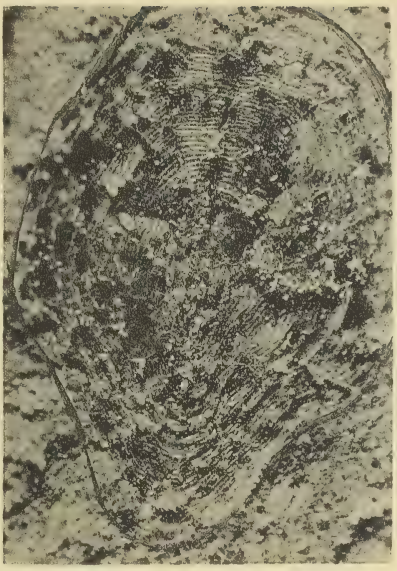

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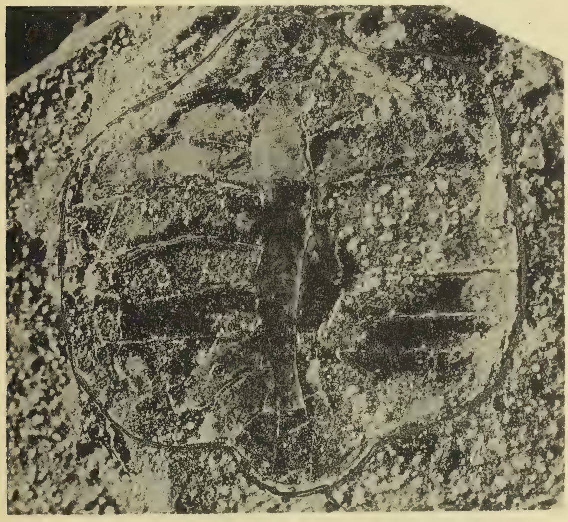

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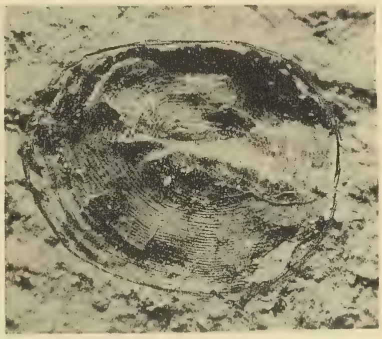

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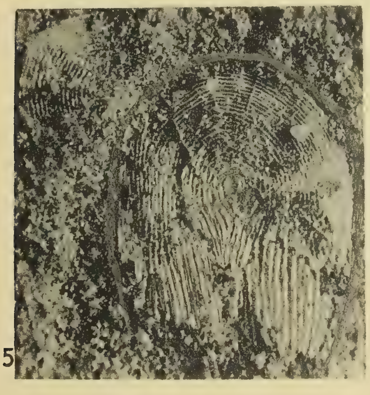

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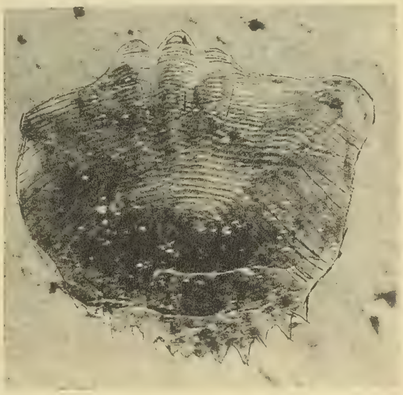

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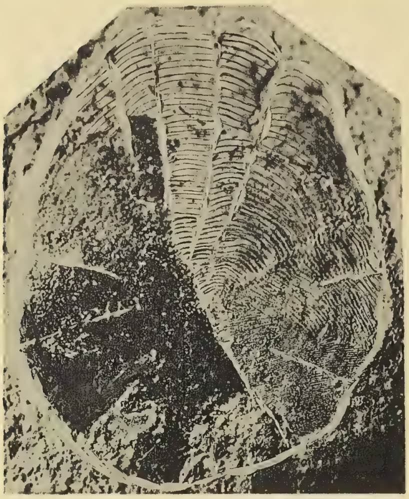
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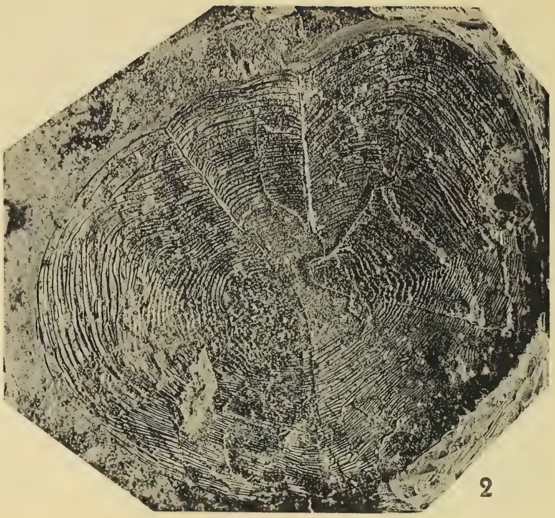
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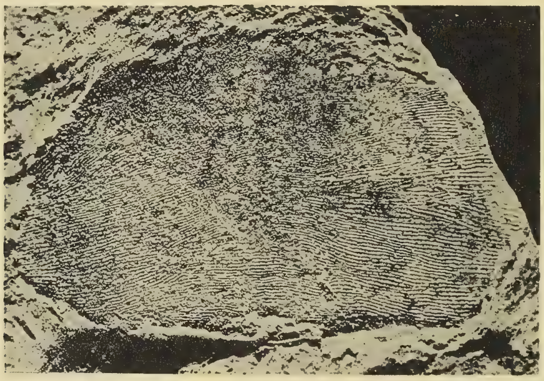
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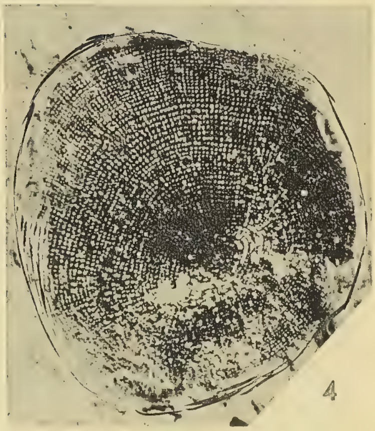
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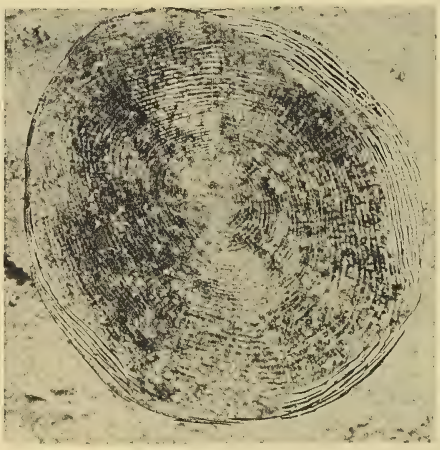
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PLATE 2

UPPER EOCENE SCALES, KREYENHAGEN FORMATION, SAN JOAQUIN VALLEY, CALIFORNIA

FIG. 1. *Hemiexocoetus eocenicus,* n. g. and n. sp. Scale 8 mm. long by 6.3 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

FIG. 2. *Hemiexocoetus eocenicus,* n. g. and n. sp. Coarse side of regenerated lateral scale 9.8 mm. long by 10 mm. deep. Seaboard Oil Corp. well, Gill No. 1.

FIG. 3. *Praescomberesox pacificus,* n. g. and n. sp. Cotype, no. 10326 C.I.T. Scale 4.1 mm. long by 7 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

FIG. 4. *Cyclolepoides tuberculatus,* n. g. and n. sp. Glossy side of scale 2 mm. long by 2.8 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

FIG. 5. *Cyclolepoides tuberculatus,* n. g. and n. sp. Coarse side of scale 4 mm. long by 2.5 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1.

PLATE 3

EOGENE SCALES, SAN JOAQUIN VALLEY, CALIFORNIA

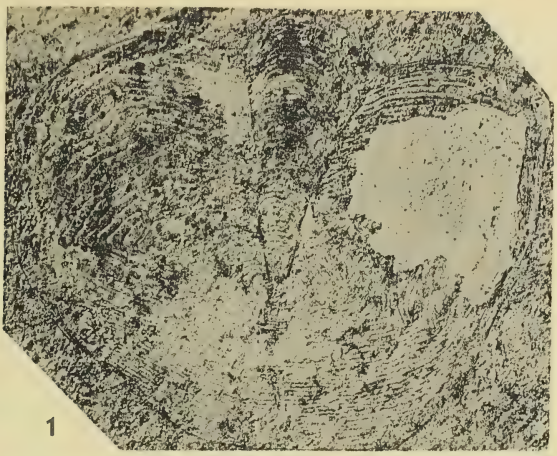
FIG. 1. *Hemiexocoetus eocenicus,* n. g. and n. sp. Scale 4 mm. long by 5 mm. deep. Seaboard Oil Corp. well, Gill No. 1. Kreyenhagen formation.

FIG. 2. *Praescomberesox pacificus,* n. g. and n. sp. Scale 8 mm. long by 7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

FIG. 3. *Beryx san-joaquinensis,* n. sp. Scale 5.75 mm. long by 5.6 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

FIG. 4. *Kreyenhagenius joaquinensis,* n. g. and n. sp. Type, no. 10318 C.I.T. Scale 5 mm. long by 5.8 mm. deep. Seaboard Oil Corp. well, Gill No. 1. Kreyenhagen formation.

FIG. 5. *Paramorone eocenica,* n. g. and n. sp. Type, no. 10317 C.I.T. Scale 5.5 mm. long by 5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.



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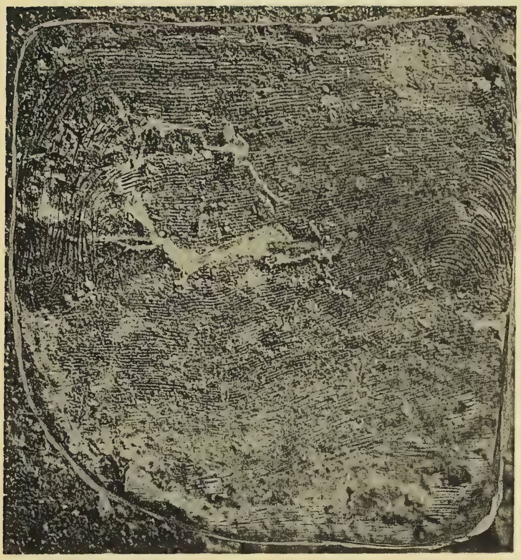

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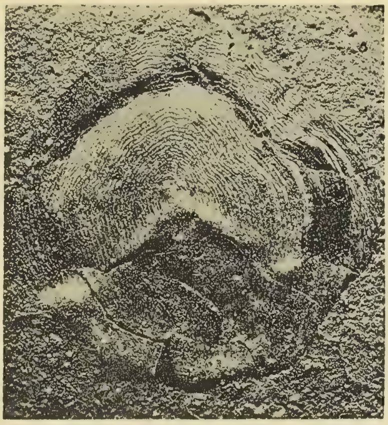

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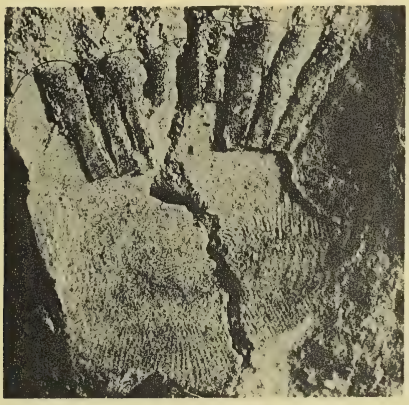

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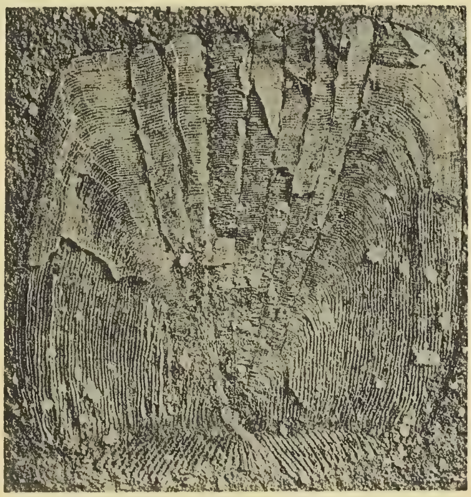

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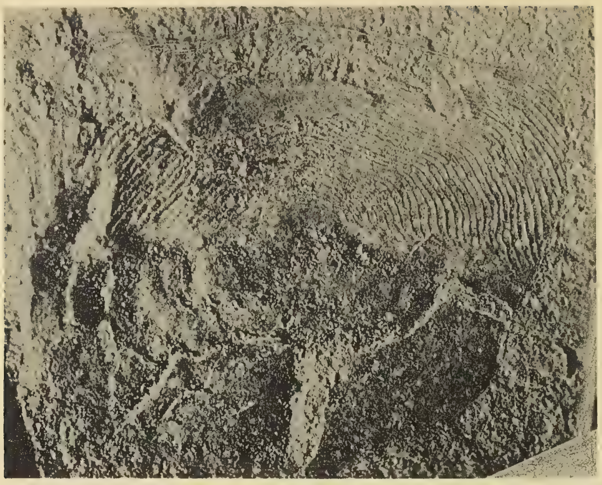

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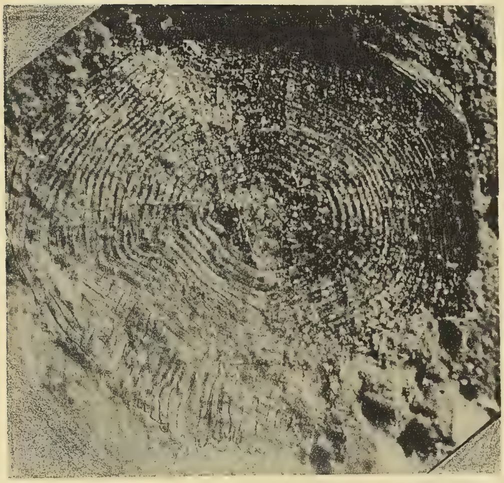

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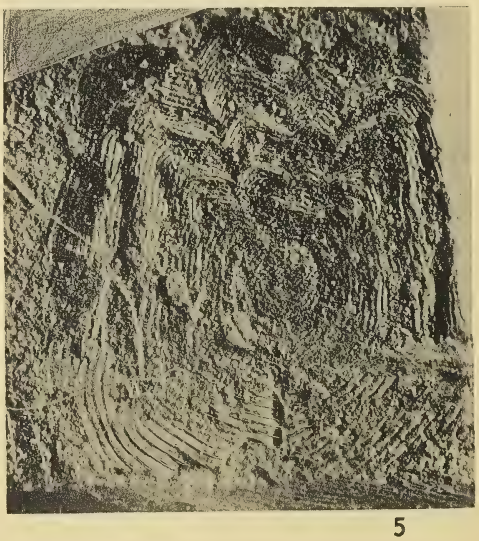

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PLATE 4

EOGENE SCALES, SAN JOAQUIN VALLEY, CALIFORNIA

FIG. 1. *Beryx san-joaquinensis,* n. sp. Scale 4 mm. long by 4.9 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

FIG. 2. *Eoscombrus chaneyensis,* n. g. and n. sp. Type, no. 116 Richfield Pale. Lab. Scale 3.9 mm. long by 3.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

FIG. 3. *Beryx eogenus,* n. sp. Type, no. 118 Richfield Pale. Lab. Scale 4.5 mm. long by 5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

FIG. 4. *Parastenodus gillensis,* n. g. and n. sp. Type, no. 110 Richfield Pale. Lab. Scale 5.2 mm. long by 3.9 mm. deep. Seaboard Oil Corp. well, Gill No. 1. Kreyenhagen formation.

FIG. 5. *Beckius plicatus,* n. g. and n. sp. Type, no. 111 Richfield Pale. Lab. Scale 4.5 mm. long by 4.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1. Tumey formation.

V

Upper Cretaceous Fish Remains from the Western Border of the San Joaquin Valley, California

Lore Rose David

With three plates and eleven text figures

[ISSUED JANUARY 25, 1946]

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Upper Cretaceous Fish Remains from the Western Border of the San Joaquin Valley, California

Introduction

The only previously recorded Cretaceous fish fossils from California are four scales described by Cockerell (1919). These represent three types, *Chicolepis punctatus, Pomolobus*? *chicoensis,* and *Erythrinolepis chicoensis,* from the Moreno formation on the south side of Ortigalito Creek; and one additional form, *Echidnocephalus*? *pacificus,* possibly from the Moreno between Little Panoche and Ortigalito creeks in the middle Coast Ranges. Fortunately a much more considerable amount of Cretaceous fish fossil material is available for the present report. Most of this comes from oil-well cores from the middle San Joaquin Valley.

Only a limited number of localities yielded materials for study; this fact is the more unusual in that Cretaceous deposits are widespread in the state. Even so, the present collection does include many well preserved forms, some of which occur in great abundance. Fortunately the total collection gives a representative cross section of the piscine fauna and comprises such families as might be expected. A satisfactory representation of the genera likewise is found. The more important members of the Upper Cretaceous fish faunas of California appear to be found among forms from Panoche Creek, and these may well serve as a foundation for future studies of related fish types.

Considerable difference prevails between the fishes of the Cretaceous and those of the early Tertiary. Cockerell (1919, p. 169) emphasizes this fact when he states: "It ought to be possible as a rule to distinguish a Cretaceous from a Tertiary deposit by means of a single well preserved fish scale." Since the relationships of extinct Cretaceous forms to existing fish cannot be ascertained in many instances, an interpretation of the ecological conditions during the time of accumulation of Cretaceous faunas must be made with caution. If large assemblages are considered, however, it seems likely that some pertinent suggestions will be feasible. Considerable interest is being shown by geologists in the California Cretaceous, and investigation of Cretaceous fish may throw light on sedimentary problems and assist in the correlation of the marine deposits of this period. The present studies are regarded as only a beginning in this direction.

Many Cretaceous fish faunas are known from other parts of the world. Of these the more important are: English chalk (Woodward, 1902–1911), Westphalia (von der Marck, 1863, 1876; von der Marck and Schlueter, 1865–1868), Saxony (Geinitz, 1868), Bohemia (Fritsch, 1878), Mount Lebanon, Syria (Davis, 1887; Hay, 1903*a*; Woodward, 1942), various parts of North America (Hay, 1903*b*, 1929; Cockerell, 1919), and Brazil (Jordan and Branner, 1908; Woodward, 1907; Maury, 1930, 1936). These faunas are known for the most part by skeletal remains. In Geinitz' paper (1868) scales are occasionally shown. Scales, when preserved in association with and overlying skeletal material of fish, cannot be clearly recognized. In many cases, therefore, it is not certain whether a particular scale belongs to a type of fish described on the basis of skeletal remains. Careful comparison with known material may in time furnish definite proof of association. Cretaceous fish remains from North America and England are almost invariably fragmentary, whereas in Westphalia and in the platy chalk of Mount Lebanon complete fish are well preserved.

The present report, for the most part, describes fossil fish remains that occur in cores of oil wells drilled along the west side of the San Joaquin Valley, near Chowchilla and Panoche Creek. Only a single set of samples was used from each well. Each of these had been utilized previously in a study of the fossil foraminifera. Most of the fish remains occurring in the well cores are scales, although bones of gill covers, vertebrae, and teeth are found occasionally. For the most part only the scales have been studied. This material is described in the hope that use may be made of it in stratigraphic investigations. A detailed comparison and correlation of the Californian forms with fish types known from Cretaceous deposits in other parts of the world will doubtless be made in the future.

Most of the new genera are named for micropaleontologists of California.

Available Material

The core samples in which the fish remains occur were taken from the following wells: (1) Jergins Oil Company, Chaney Ranch No. 1, Panoche district, Sec. 29, T. 14 S., R. 13 E., Mount Diablo base line and meridian, total depth 9284 feet; (2) Western Gulf Oil Company, Lillis Welch No. 1, Firebough district, Sec. 26, T. 15 S., R. 12 E., Mt. Diablo B. and M., total depth 5624 feet; (3) Pure Oil Company, Chowchilla No. 1, Chowchilla district, Sec. 7, T. 10 S., R. 14 E., Mt. Diablo B. and M., total depth 8387 feet. Included in the report are also some large fish remains found in the Moreno formation of the Panoche Hills. From these deposits have come also remains of mosasaurs and plesiosaurs.

Description of Fish Fauna

ORDER SELACHII

Family LAMNIDAE. Mackerel Sharks

Corax sp.

(Text figure 1)

A small shark's tooth of the genus *Corax* was found in the Jergins Oil Co. well, Chaney Ranch No. 1, between the depths of 6206 and 6215 feet in the Moreno shale. The specimen measures 5 mm. in length, including the root, and 3.2 mm. in width.

The tooth is moderately broad; crown almost erect, moderately convex, emarginate at the base. Cutting edges serrated; serrations much stronger on straight edge than on indented side.

This form seems to be distinguished from known species of the genus by a slightly different shape; one side is strongly indented and the other is concave. It differs also in having a very long, bifurcated root, and in having strong serrations on one side only, the opposite edge, including the indentation, being only feebly serrated. The tooth does not appear to belong to any known form, and probably represents a new species. Since *Corax* is not otherwise known from California, and since only one specimen has been found so far, it does not appear advisable to establish a new type. *Corax* is typical of the Cretaceous, but occurs occasionally in the Eocene.

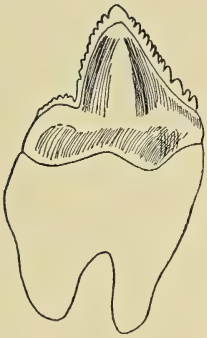


Fig. 1. *Corax* sp. Tooth 5 mm. long by 3.2 mm. wide. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6206 to 6215 feet. Moreno formation.

ORDER HOLOSTEI

Family PACHYCORMIDAE

Protosphyraena sp.

A large pectoral fin of this genus, no. 10125, Calif. Inst. Tech. Vert. Pale. Coll., was found at C.I.T. locality 355 (north branch of Moreno Gulch, NW. ¼ Sec. 11, T. 14 S., R. 11 E., Mt. Diablo B. and M.). *Protosphyraena* Leidy is abundantly represented in the Niobrara of Kansas and is known also from the Benton and Pierre.

ORDER OSTARIOPHYSI

Family ERYTHRINOLEPIDAE

Erythrinolepis cf. **chicoensis** Cockerell

(Plate 2, figure 5)

Description. Specimens show the following variable proportions of length to depth (in millimeters): 15 to 13, 13 to 13, 12 to 12.5, 10 to 10. Differences between the two sides of a scale are well defined. Outer side smooth except for strong, irregular grooves; inner side with very fine circuli, the grooves visible only as fine lines. Grooves on smooth side wide, very irregular, originating for the most part in region of nucleus, sometimes shorter, broken or anastomizing. Majority of grooves in basal region, those on apical part fewer and thinner. Basal margin sometimes crenated, but more so on distorted specimens. Coarse side of scale with very fine concentric circuli, 32 in 1 mm. distance near outer border of specimen of 12 mm. diameter (a large number considering the size of the scales of this form); circuli somewhat coarser in larger scale. Circuli not recognizable in apical region. Fine, irregular tuberculations visible on anterior part of apical region; feeble apical radii probably also present. Grooves on smooth side present only as simple dividing lines; on coarse side, dividing circuli into foldlike sections; these lines are not strong, nor do they project vertically as on smooth side. Nucleus above lower third of scale. Scales evidently delicate, thinner than the average Cretaceous scale of this size. Scale rarely well preserved; when present it is usually preserved as a mold of smooth side, showing the grooves mentioned above as strong ridges.

Occurrence. Erythrinolepis is found nowhere in abundance, but it occurs occasionally in the Moreno as well as in the Panoche formation in wells in the Big Panoche Creek region. The only well preserved specimen comes from a depth of 7137 to 7144 feet in the Jergins Oil Co. well, Chaney Ranch No. 1.

Relationships. Cockerell's species *E. chicoensis* was established on comparatively few specimens from the Moreno formation of Ortigalito Creek. These were not available for comparison with the material described in the present paper. It is not certain, therefore, that both occurrences represent the same species. Cockerell (1919) described another species of the genus from the Mowry shale of Wyoming. He considers *Erythrinolepis* to be most closely related to the Erythrininae, freshwater fishes of South America.

Scales of the Wyoming Upper Cretaceous species are smaller than the present material, the circuli are considerably coarser, and there is a definite difference in the structure of the apical region. The latter in *E. mowriensis* shows a very fine circuli-like ornamentation into which the coarse circuli of the basal region change abruptly. The apical lines have an anteroposterior direction in the middle of the apical part and are transverse in the dorsal and ventral sectors of the apical region, whence they gradually change their direction toward the anteroposterior central lines. This structure of the apical pole is probably not unique in *Erythrinolepis mowriensis.* Indication of a similar structure was observed in *Holcolepis transversus* Cockerell. In the latter form it occurs in the nuclear center above the region where the coarse apical radii are formed, but is noticeable only in well preserved scales. This may indicate relationship between the two scales. In typical specimens of *H. transversus,* however, the basal part is never divided into folds as in *Erythrinolepis.* Typical scales of *Erythrinolepis* never show an indication of the coarse apical structure seen in *H. transversus.* An apical structure similar to that shown in *E. mowriensis* is also found in scales of the Heteromi, a group far removed from the two genera to which reference has been made. It may be a structure shown by a number of primitive forms, including those mentioned above.

The California scales here described do not show a similar apical structure. The apical region has only faint radii and tubercles. The scales resemble those of *E. mowriensis* in having very strong, irregular basal radii, vertically projected on the smooth side, but less conspicuous on the coarse side of the scale. This latter character seems to be the outstanding feature common to the species of this peculiar fossil genus.

Relationships of the fossil genus are uncertain. There is undoubtedly a similarity to the Recent Erythrininae, but whether this is due to descent or not cannot be determined. The Erythrininae have basal radii of the same structure, but differ in other characters. The fossil scales do not show a division of their central part into irregular cells, as is the case generally among the Erythrininae; the structure of the apical pole is also totally different.

ORDER ISOSPONDYLI

Family PACHYRHIZODONTIDAE

Pachyrhizodus sp.

(Plate 1, figure 2)

Material and location. A number of large skeletal fragments evidently belong to this genus. These include: A caudal fin together with the end of the vertebral spine, no. 10126, Calif. Inst. Tech. Vert. Pale. Coll., from C.I.T. locality 362, Moreno formation of the Tumey Hills. A left half of a jaw, no. 10123 C.I.T., from diatomaceous beds in the lower part of Quail Canyon, Panoche Hills, C.I.T. locality 358. A large pectoral fin and several jaw fragments, no. 10124 C.I.T., from C.I.T. locality 359, at 150 feet above base of Moreno in first canyon north of Reptile Ridge. Isolated vertebrae of this genus are also present.

Description of scale. The large scale figured in plate 1, figure 2 may belong to this genus. It measures 20.5 mm. long by 23 mm. deep, and was found in the Moreno shale of the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4954 to 4960 feet. The basal part seems badly squeezed or damaged by small pieces of gravel, and no circuli or other structures are recognized. The strengthened basal margin is well preserved, however, showing a distinct median notch. The apical pole shows well preserved tuberculate radii comparatively near to each other, divided by shallow grooves, about 15 in a distance of 5 mm. Upper border of apical pole rounded, lower margin partly fragmented, evidently rounded to pointed. Apical radii resemble those found in *Holcolepis transversus,* but are finer and closer together; the tubercles are much smaller and do not protrude as much above the surface of the radii.

Discussion. The scale of *Pachyrhizodus* is said to have tuberculate radii in the apical pole comparable to those of *Holcolepis,* and a smooth basal region. *Pachyrhizodus subulidens* (Owen), a small species from the English chalk, as figured by Woodward (Fishes of the English chalk, 1908), has a scale much longer than deep, whereas the California scale is deeper than long. Such proportions, however, may differ considerably in different species of one genus.

Family ELOPIDAE. TARPONS AND TEN-POUNDERS

Holcolepis nodulatus, n. sp.

(Plate 2, figure 4)

Type. No. 10333, Calif. Inst. Tech. Vert. Pale. Coll. Scale 13 mm. deep, preserved part 10 mm. long, uppermost border missing.

Type locality. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4387 to 4396 feet. Moreno shale, Upper Cretaceous.

Description. Type is a mold of coarse side of scale, with greater part of apical region of actual scale preserved. About 4 feebly marked basal folds present. Circuli in crescentic lines around nucleus, twice as wide as high; circuli comparatively fine in nuclear region, 30 to 32 in 1 mm. distance, coarser toward outer border, with 22 in 1 mm. distance. Nucleus probably near middle of scale, immediately above uppermost point of apical section. Apical region broad, occupying basal border completely, forming a triangle with its upper angle of nearly 120° directed toward nucleus. Apical region composed of coarse tuberculate ridges, slightly less than 5 in 1 mm. Disk-shaped nodules spaced on upper surface of ridges, nodules with round cavities at their tips. Fine tubercles in area below nucleus and around uppermost ends of apical radii, tubercles increasing in size toward apical area, the uppermost part of which is more densely occupied with them. Scale pyritized.

Relationships. The scale is fragmentary along its basal margin; otherwise it shows the characteristics of *Holcolepis* von der Marck. Among the species of the genus it appears to have the greatest affinity to *H. transversus* Cockerell, a form abundant in the Benton and Mowry shale of Wyoming and Colorado. *Holcolepis nodulatus* has finer circuli than any other known species of the genus. It is also distinguished by the structure of the apical radii, which are quite broad and resemble in this respect *H. transversus.* The radii are continuous, however, and not as in *H. transversus,* where they are subdivided into overlapping sections, the lower ones sometimes pointed at the apical ends in the manner of spines. In *H. nodulatus* disk-shaped nodules are spaced on the apical radii, distinguishing this form from all other known species. So far, only the type scale has been assigned to the species. Some of the less well preserved scales attributed tentatively to *Erythrinolepis* show some similarity to the type and may belong here.

The genus *Holcolepis* is well known from the Upper Cretaceous of continental Europe and the English chalk, as well as from Syria. It was a medium-sized fish related to the modern tarpons.

Holcolepis angulatus, n. sp.

(Plate 2, figure 6)

Type. No. 10334, Calif. Inst. Tech. Vert. Pale. Coll. Scale 12.4 mm. long by 14 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6654 to 6663 feet. Moreno shale, Upper Cretaceous.

Description. Scale almost round, with an average diameter of 13 mm. Basal region with a number of very indistinct folds. Circuli very strong, coarse, 17 to 18 in 1 mm. distance, curving upward from apical section in half circles to right and left and meeting in acute angles in middle of basal part of scale; bisecting line of angles not quite in center of scale, but deviating slightly toward ventral side. Sides of angles widely curved before meeting in apex. Nucleus above lower two-fifths of scale, exactly above center of apical section. Apical part forms a small triangle, with upper angle of 60°; comparatively dense tuberculate ridges are present, 12 in 1 mm. distance, 60 in number. Region below nucleus and uppermost point of apical section ornamented with closely spaced tubercles.

Relationships. Holcolepis angulatus has a large, well characterized scale with strong, rounded circuli, distinctly angular in a median diameter, and with dense tuberculate apical ridges ornamenting the small triangular apical pole. The new species is nearly related to *H. pulchellus* Cockerell, described from a locality in Colorado believed to be of Benton shale age. *Holcolepis angulatus* is distinguished by the robustness of the scale, the coarser circuli, and their pronounced median angles.

Laimingia plicata, n. g. and n. sp. Ten-pounder

(Plate 1, figures 3, 4; text figure 2)

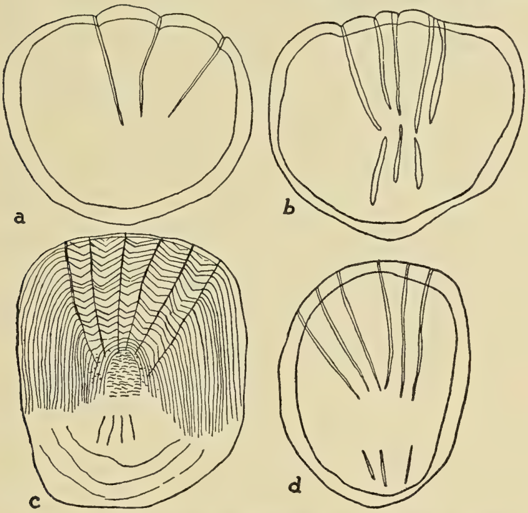


Fig. 2. *Laimingia plicata,* n. g. and n. sp. (*a*) Smooth side of ovoid scale 3 mm. long by 3.5 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4396 to 4400 feet. Moreno formation. (*b*) Mold of smooth side of rounded scale, counterpart of specimen shown in plate 1, figure 4; 4 mm. long by 4.1 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6605 to 6608 feet. Moreno formation. (*c*) Coarse side of pyritized elongate scale 3 mm. long by 2.8 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6437 to 6443 feet. Moreno formation. (*d*) Smooth side of elongate scale 2.9 mm. long by 2 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4396 to 4400 feet. Moreno formation.

Genotype. No. 10307, Calif. Inst. Tech. Vert. Pale. Coll. Scale 3.2 mm. long by 4.1 mm. deep.

Type locality. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4436 to 4451 feet. Moreno formation.

Description. Scales quite variable in shape and structure, smooth and coarse sides very different. Length and depth (in millimeters) of ovoid scales, 4.9 by 5, 4.2 by 5, 3.2 by 4.8, 3 by 4.3, 2.3 by 3, 2.2 by 3, 2.1 by 3, 2 by 2.9; of elongate scales, 4.5 by 4, 4 by 3, 3.9 by 2.9, 3 by 2.5, 2.8 by 2.5; of rounded scales, 3.1 by 3.9, 3.1 by 3.1, 3 by 3. Scales small compared with those of other Cretaceous forms belonging to the family. Largest scales ovoid (pl. 1, fig. 3; text fig. 2*a*), probably belonging to midlateral and dorsal series on anterior part of fish. Ventral scales smaller, elongate (text fig. 2*c*, *d*) to rounded (text fig. 2*b*; pl. 1, fig. 4). Scales of posterior half of body evidently also decrease in size; probably of rounded type; lateral-line scales small, not conspicuous. Basal part of scale with robust circuli variously plicated, apical part smooth, central part reticulated. Scales comparatively thick, smooth side almost entirely even, marked only by a variable number of grooves on basal side which indicate the ridges of the plications of the basal folds; three short grooves generally present on apical part of smooth side in elongate and rounded scales, these not so well marked as basal ones. Ovoid scales with robust, almost completely transverse circuli. Few plications on ovoid scales, usually only 2 folds; 12 to 13 circuli in 1 mm. distance in middle part of type, 16 to 17 in a larger specimen of 5.5 mm. depth from Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Reticulations form a broad transverse band throughout width of scale, band deeper in center. Apical region completely smooth. Elongate and rounded scales with circuli rounded, 20 to 21 in 1 mm. distance on basal part of scale, turning toward apical region at dorsal and ventral margins and approaching each other. About 30 circuli in 1 mm. distance dorsally and ventrally to nucleus. Apical region free of circuli. A variable number of plications in basal region, usually 3 to 6; plications of variable width; circuli plicated in acute angles. Reticulation restricted to center of scale. Apical pole smooth except for a small number of short longitudinal ridges in its center. In pyritized scales the apical region is a deep brown, the upper two-thirds a golden color; scales when not pyritized have dark-brown color.

The new genus is named for Mr. Boris G. Laiming, paleontologist of the Texas Company, California.

Occurrence. This is one of the most abundant scales found in the Upper Cretaceous of the Big Panoche Creek area. Pyritized specimens are often found with *Kleinpellia* in the Moreno formation and abundantly again in the uppermost Panoche with *Driverius* and *Paraberyx*. It occurs in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6231 to 6300 feet, 6437 to 6616 feet, and 7096 to 7144 feet. In the Western Gulf Oil Co. well, Lillis Welch No. 1, it occurs downward from 4375 feet. A few scales were found at depths from 5010 to 5083 feet in the Pure Oil Co. well, Chowchilla No. 1.

Laimingia is evidently more closely related to *Elops,* the ten-pounder, than to any other of the numerous elopine fishes found in the Cretaceous deposits over the world. It shows a similar arrangement of basal and apical poles and central reticulations. The circuli in *Elops* are finer, the plications are rounded and much more numerous, and apical radii are present. The majority of the Cretaceous Elopidae seem to have much larger scales, similar to those of *Holcolepis.* Closely related to *Laimingia* seem to be *Trissopater* Guenther and *Rhacolepis* Agassiz, both with scales of moderate size. Neither of these forms has the strong plications seen in *Laimingia. Rhacolepis* is more primitive than *Laimingia* and shows less similarity to the scale of *Elops;* the circuli show few plications in the basal region and form very acute basolateral angles; the circuli are more widely spaced in *Rhacolepis* than in *Laimingia,* but are not so coarse. The reticulation markings are more widely spaced than the circuli and are arranged in lines. They are not readily distinguishable from the circuli above the nucleus.

Elops, the only surviving genus of this family today, lives in warm seas near shore, frequents lagoons, and enters the mouths of rivers. The numerous elopid fishes of the Cretaceous probably occupied a wider variety of habitats, and, like the tarpon of today, of the related family Megalopidae, were not so restricted to near-shore environments. There is not much doubt that they all were inhabitants of warm coastal seas.

Helmintholepis sp.

(Plate 3, figure 1)

A very large scale, measuring 16.5 mm. long by 21 mm. deep, was recovered from the Jergins Oil Co. well, Chaney Ranch No. 1, at a depth from 6605 to 6608 feet. Moreno formation.

Description. Basal region, where actual scale is preserved, with concentric circuli, fine for size of scale (30 in 1 mm. distance at basal margin) and grouped close together. Nucleus in or near center of scale. Fine apical radii indistinctly present on mold of original scale; radii wavy, not close together. Basal margin of scale with strengthened rim, indented in median line. Smooth side of scale with numerous fine tubercles.

Discussion. This scale is tentatively assigned to Cockerell's genus *Helmintholepis.* It has similar characters, although the apical radii are more closely set in Cockerell's species *H. vermiculatus,* and the scales are longer than deep. Some similarity likewise exists between the California scale and that of the large genus *Hypsodon.* It is doubtful to which family *Helmintholepis* belongs.

Family ALBULIDAE. Ladyfishes

Kleinpellia morenoensis, n. g. and n. sp.

(Plate 1, figure 1; text figure 3*a, b*)

Type. No. 10304, Calif. Inst. Tech. Vert. Pale. Coll. Scale 7.2 mm. long by 7 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6595 to 6605 feet. Moreno formation.

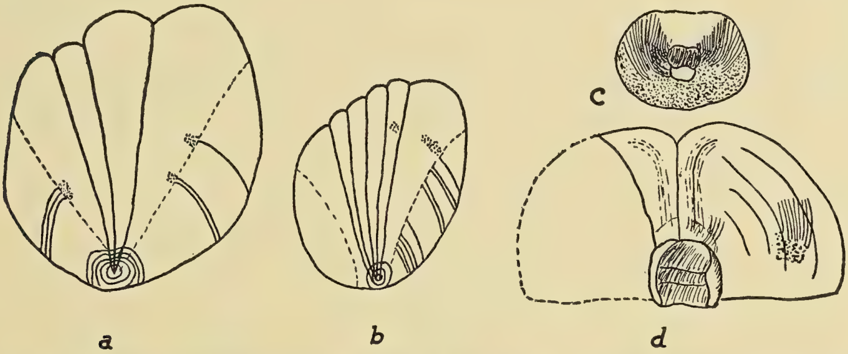


Fig. 3. *Kleinpellia morenoensis,* n. g. and n. sp. (*a*) Type, no. 10304 C.I.T. Scale 7.2 mm. long by 7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6595 to 6605 feet. Moreno formation. (See also pl. 1, fig. 1.) (*b*) Scale 6 mm. long by 4.2 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6492 to 6497 feet. Moreno formation. (*c*) Lateral-line shield of *Kleinpellia*?, 4 mm. long by 3 mm. deep. Pure Oil Co. well, Chowchilla No. 1, at depth from 4977 to 5049 feet. Panoche formation. (*d*) Lateral-line shield of *Kleinpellia*?, 5 mm. long by 8.4 mm. deep. Pure Oil Co. well, Chowchilla No. 1, at depth from 4737 to 4751 feet. Panoche formation.

Description. Scales longer than deep. Measurements (in millimeters) of length and depth in typical scales: 7.5 by 6.8, 7 by 6, 6 by 4.2. Two to 4 long basal folds present, extending toward apical focus. Folds of irregular width, the central one often much broader than others. Basal and apical borders and, to a lesser extent, dorsal and ventral borders rounded. Basal border scalloped; scallops slight, rounded. Longitudinal circuli present in apical part of scale, rounded toward median line and continuing through three-quarters length of scale on outer borders. Circuli comparatively coarse, 17 in 1 mm. distance on scale 7.5 mm. long. Basal part and entire middle covered by tuberculations comparable to those found in the living *Albula* and *Dixonina,* but much less regularly arranged. Nucleus apical, surrounded by a number of circuli that form almost a complete circle; longitudinal circuli in dorsal and ventral parts of apical pole terminate directly in apical border. In *Albula* and *Dixonina* a thin, smooth border continues scale at apical pole. This border may have been lost in the fossils.

The new genus is named for Mr. Robert M. Kleinpell, paleontologist.

Occurrence. Kleinpellia is abundant in certain sections of the Moreno formation near Big Panoche Creek, and is found occasionally in the Panoche formation. It occurs in cores of the following wells: Jergins Oil Co., Chaney Ranch No. 1, at depth from 6287 to 6292 feet, and more abundantly between 6437 and 6605 feet; Western Gulf Oil Co., Lillis Welch No. 1, at depth from 4436 to 4451 feet; Pure Oil Co., Chowchilla No. 1, at depth from 4977 to 5010 feet. Specimens from the first two wells were found in the Moreno formation, those from the third well in the Panoche formation. Most of the scales were pyritized.

This scale is more similar to scales of living albulids than any fossil found before. The basal border of the scale is not so strongly scalloped, however, and the scallops are not pointed. There are differences in the reticulations and tuberculations and in the formation of the apical pole, as is mentioned above. The albulids represent primitive types of fishes among the Isospondyli, the two surviving genera, *Albula* and *Dixonina,* having been regarded as relict forms of a once more widely distributed family. Existence of a variety of albulids in the Upper Cretaceous might therefore be expected. It is interesting to note that the California deposits are the first to yield true albulid forms for this period. Living Albulidae are known from pelagic regions of warm coastal seas. Since the modern forms have retained many of their primitive features, it may be safe to conclude that the family occupied essentially the same habitat in Cretaceous time as it does today.

Lateral-Line Shields Tentatively Referred to Kleinpellia

(Text figure 3*c, d*)

Certain bony structures are found occasionally in stratigraphic horizons where *Kleinpellia* also occurs. These show an ornamentation similar to that of the scale of *Kleinpellia,* and may be lateral-line scutes of this form. These structures have different dimensions; the scutes probably varied in size in the same specimen, decreasing in diameter toward the caudal end. Measurements (in millimeters) of length and depth of individual scutes vary as follows: 5 by 8.4, 4 by 3, 2 by 2.5.

The largest scute shows the following characters: Posterior end smooth, notched in middle line, posterior border of both halves rounded; anterior border almost straight or slightly concave, interrupted by very prominent cavity for lateral-line channel. Circuli originate at some distance from posterior border, curve forward, and are lost anteriorly in a group of densely placed irregular tubercles. This ornamentation closely resembles that found on scales of *Kleinpellia.* Smaller scutes show smooth apical region restricted to middle of apical pole, or missing. Lateral-line cavity varies in position.

Occurrence. Moreno formation at depth from 6507 to 6514 feet, Jergins Oil Co. well, Chaney Ranch No. 1. Panoche formation at depth from 4737 to 4751 feet and from 4977 to 5049 feet, Pure Oil Co. well, Chowchilla No. 1.

Family ICHTHYODECTIDAE

Ichthyodectes sp.

One small fragment representing not quite half a scale, from the Pure Oil Co. well, Chowchilla No. 1, at depth from 4977 to 5010 feet, in the Panoche formation. The original scale measured approximately 4 mm. long by 9 mm. deep. The scale shows numerous short grooves in the basal region; concentric circuli are present in the basal part. The apical part is smooth except for indistinct reticulations.

Family CLUPEIDAE. Herrings

Driverius cretaceus, n. g. and n. sp.

(Plate 3, figures 3, 4; text figure 4)

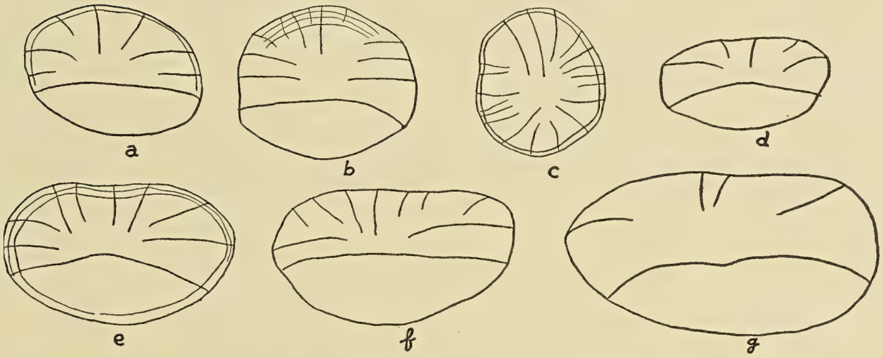


Fig. 4. *Driverius cretaceus,* n. g. and n. sp. (*a*) Scale 3 mm. long by 4 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 5060 to 5065 feet. Panoche formation. (*b*) Scale 3.5 mm. long by 4 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7130 to 7137 feet. Panoche formation. (*c*) Scale 3.5 mm. long by 3 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. (*d*) Scale 2.2 mm. long by 3.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7086 to 7095 feet. Panoche formation. (*e*) Scale 3.8 mm. long by 5.2 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 5060 to 5065 feet. Panoche formation. (*f*) Scale 3.9 mm. long by 5.1 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7130 to 7137 feet. Panoche formation. (*g*) Scale 4 mm. long by 7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7086 to 7095 feet. Panoche formation.

Type. No. 10305, Calif. Inst. Tech. Vert. Pale. Coll. Scale 3 mm. long by 4 mm. deep.

Cotype. No. 10306, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.1 mm. long by 7 mm. deep.

Type locality. Type from Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Cotype from the same well, at depth from 7003 to 7009 feet. Panoche formation.

Description. Scales oval, much deeper than long. Measurements (in millimeters) of length and depth of typical specimens: 5 by 6, 4 by 7, 3 by 5, 3.5 by 4.25, 3 by 3.5. Circuli in basal region almost entirely transverse, basal circuli finer near nuclear area, much coarser at lateral margins, 30 to 32 circuli in 1 mm. distance at dorsal margin;

34 to 36 in 1 mm. distance dorsal to nucleus in average scale 3 mm. long by 5 mm. deep. Three to 9 basal radii, spreading in various directions; apical and basal parts of scale divided by a transverse radius. One or 2 paired transverse radii present, very rarely more; 1 to 7 longitudinal basal radii directed toward nucleus, their direction variable. Apical pole smooth, structureless. One to 3 folds on outer border of scale in majority of scales. Ventral scutes, typical of the true herrings, found with scales.

The new genus is named for Mr. Herschel L. Driver, paleontologist of the Standard Oil Company of California.

Occurrence. This scale is extremely abundant in the uppermost layers of the Panoche formation in the region of Big Panoche Creek. It occurs abundantly in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7003 to 7144 feet, and in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4886 to 5242 feet.

This species is clearly related to the group of Clupeidae characterized by a long tail part, long anal fin, and short head and thoracal part of body. Representatives of this group are the genera *Pellona, Opisthopterus, Pristigaster, Pliosteostoma.* Like these, *Driverius* has oval scales that are deeper than long. Furthermore, vertical basal radii are present in variable number and direction, whereas paired transverse radii are reduced in number. No close relationship to any one species can be established. *Driverius* shows similarity to *Pliosteostoma lutipinnis,* which lives today along the Pacific coast of Mexico. In the former type, however, the scale has a smooth apical pole, the circuli are more strictly transverse, and the basal radii are straighter and differently arranged. All the types belonging to this group of herrings are inhabitants of warm coastal waters, especially near river mouths.

Bramlettia cf. **chicoensis** (Cockerell)

(Text figure 5)

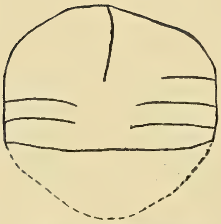


FIG. 5. *Bramlettia* cf. *chicoensis* (Cockerell). Basal part of scale 5.5 mm. long by 8 mm. deep; apical part restored. Pure Oil Co. well, Chowchilla No. 1, at depth from 4737 to 4856 feet. Panoche formation.

Pomolobus chicoensis Cockerell (1919).

Description. Only two scales of this form have been found. Basal part of larger one measures 5.5 mm. long by 8 mm. deep. In this specimen the apical pole is missing. Smaller scale measures 4 mm. by 4.5 mm. Scale ovoid, slightly deeper than long. Circuli almost entirely transverse in basal region; comparatively coarse, but finer in small area near nucleus; 24 to 25 circuli in 1 mm. distance near upper border of large scale, 36 to 37 in region dorsal to nuclear center. Apical and basal parts of scale divided by almost straight transverse radius; 2 to 3 pairs of transverse radii present, parallel to lower border of basal part. Two lower pairs of transverse radii close together, upper one slightly oblique and farther removed. Upper two-fifths of basal region without transverse radii; a median longitudinal fold distinct.

The new genus is named for Dr. M. N. Bramlette, of the U. S. Geological Survey.

Occurrence. Both scales were found in the Pure Oil Co. well, Chowchilla No. 1, in the Panoche formation, at depth from 4737 to 4856 feet.

The scale described by Cockerell as *Pomolobus chicoensis,* from the Moreno formation of Ortigalito Creek, may be specifically identical with the scales described above. The Panoche Creek form, however, is not comparable to the living *Pomolobus.* The latter is larger than the fossil described by Cockerell and shows a more detailed sculpturing. *Bramlettia* differs from the living *Pomolobus* in the arrangement and in the smaller number of paired transverse radii, and in the large size of that part of the basal pole free of such radii. Small scales of *Bramlettia chicoensis* appear to resemble the young of *Pomolobus pseudo-harengus,* but more clearly defined differences appear in the larger scales.

Family ENCHODONTIDAE

Enchodus sp.

Upper and lower jaws as well as parts of the vertebral column of an enchodontid fish, evidently a species of the genus *Enchodus* Agassiz, were found associated with the skeleton of a mosasaur, no. 2750, Calif. Inst. Tech. Vert. Pale. Coll., at C.I.T. locality 331, 440 feet above the base of the Moreno formation exposed in NW. ¼ Sec. 36, T. 14 S., R. 12 E., Mt. Diablo B. and M. This fish had served as food for the marine reptile.

Family SALMONIDAE. Salmons

Natlandia ornata, n. g. and n. sp.

(Plate 2, figures 1, 3)

Type. No. 10308, Calif. Inst. Tech. Vert. Pale. Coll. Scale 7.7 mm. long by 5.2 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6507 to 6514 feet. Moreno formation.

Description. Comparatively large ovoid to round scales, longer than deep. Measurements (in millimeters) of length and depth vary as follows: 9 by 6.9, 7.2 by 6, 6.3 by 6, 6.9 by 5.9, 5.5 by 6.1, 5.2 by 4.4, 4.1 by 3.2, 3 by 2.5. No basal folds. Uniform concentric circuli occupy basal, dorsal, and ventral parts of scale; apical region almost smooth. Nucleus high, situated above center but slightly below upper third of scale. Nucleus surrounded by more or less complete circuli that form a keystone or oval shape. Circuli thin and widely spaced, becoming increasingly coarser toward outer margin. Circuli end abruptly toward apical pole; central ones shortest, increasingly longer toward exterior margin of scale, outermost circuli almost reach apical margin. Apical region therefore forms a high triangle with acute upper angle, in contrast with that in related living scales, where circuli end in almost a straight line toward apical region. Twelve to 14 circuli in 0.5 mm. distance in nuclear region, circuli here separated by distances greater than their width; 20 to 21 in 1 mm. distance at outer margin of scale in type. Circuli very coarse here, closely set. Focal point of scale in center of nucleus free of circuli. Ornamentation present in nuclear region, spreading toward apical pole, where it is much denser; upper part of apical region often smooth. Outer margin of scale often folded 2 to 3 times; posterior border generally broken off. Comparatively feeble apical radii may be present toward outer margin of apical pole. Some scales show entire center of scale free of circuli; possibly these are regenerated or otherwise atypical scales.

Scale figured in plate 2, figure 1 probably is a lateral-line scale of this species. The circuli are finer, however, 27 in 1 mm. distance near outer margin; center of scale and apical region free of circuli; short apical radii present, central 2 strengthened. This scale may represent a different species, characterized by finer circuli. A number of additional scales (length and depth 7 by 6.5, lateral-line scale; 6.7 by 6.2, 4 by 5 mm.) seem also to show finer circuli than others. These scales seem comparatively deeper in proportion to length, but they are never well preserved. Both types occur together in the same horizons, and for the time being it does not seem advisable to assign them to different species.

The new genus is named for Mr. M. L. Natland, paleontologist of the Richfield Oil Corporation, California.

Occurrence. This form is very abundant in the Moreno and uppermost Panoche formations of the Big Panoche Creek area. It occurs in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6287 to 7137 feet, and in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4396 to 4789 feet.

Relationships. The scale shows near relationship to those of the living salmons. The arrangement of circuli on basal and apical poles is very similar. The nucleus of the Cretaceous form, however, is situated higher; the arrangement and shape of the nuclear circuli are different; the circuli also reach farther apicad at the outer margin of the scale, and do not show the straight-cut lower border found in Recent salmons. The Cretaceous scales are thicker and have a coarser ornamentation in the form of a reticulation of the apical region, especially marked in the center of the scale. This ornamentation is especially marked on pyritized scales, where it has a golden color, whereas other parts of the apical pole are a dark, glossy brown. Ichthyologists and geologists would be particularly interested in knowing the individual ages these Cretaceous salmons attained, and whether they actually were migratory fish as are the living salmons. A statement concerning these questions is difficult to make in view of the state of preservation of the fossil scales. There is also no information available as to the size of the fish and as to the specific environment in which it occurred. Both items are of significance in an attempt to interpret the habits of present-day salmon on the basis of scales. Leo Shapavalov, senior fisheries biologist of the Division of Fish and Game, State of California, who has devoted particular attention to the study of salmon, examined the Cretaceous scales and kindly furnished the following statement (letter of April 7, 1943): "The scales are all too fragmentary or regenerated for me to feel justified in attempting to state ages. Two or three show one or two checks that have the appearance of annuli, but other annuli may be obscured or obliterated. In none of the scales do I see sharply differentiated growth, as we find in present-day salmon and trout that have spent a part of their life in fresh water and a part at sea. On this basis I would say that I have no indication that the fish represented by the present scales migrated from fresh water to the sea, but I would not state positively that they had not. The more or less uniform growth in the different scales indicates that the fish had spent their lives in a similar environment." It is apparent that the environment was marine during the Upper Cretaceous time when the sediments containing the fish scales were deposited. Thus the conclusion may be reached that the Cretaceous salmon spent their entire life in the sea or possibly in brackish water. It is also likely that the majority of the fossil scales are from fish older than 1 year and probably from individuals 2 to 4 years old.

Goudkoffia delicata, n. g. and n. sp.

(Plate 2, figure 2)

Type. No. 10309, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4.2 mm. long by 4 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation.

Description. Scale rounded to oval, length and depth (in millimeters) 3.1 by 3, 4.5 by 3, 3.8 by 3. Scales generally very thin and delicate, preserved only under favorable conditions, where shale is not too strongly compressed. Basal region almost evenly rounded, showing a very faint, irregular folding; 3 to 4 vertical radii present, dividing circuli of basal region. Circuli comparatively fine, concentric, rounded in basal region, meeting in acute angle in median line of apical pole; 28 in 1 mm. distance at outer margin of basal region, those at apical pole much finer, 34 in 1 mm. distance. Nucleus almost central or sometimes above center of scale. Apical pole may be continued with smooth triangular part prolonging scale posteriorly into a thin appendage; this, however, is folded and not preserved in original condition.

The new genus is named for Dr. Paul P. Goudkoff, paleontologist, of Los Angeles, California.

Occurrence. The scale is found occasionally in the stratigraphic sequence from the Lower Moreno to uppermost Panoche formation of the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6507 to 7144 feet.

Relationships. Goudkoffia is not unlike the preceding form except for the smaller size, the finer circuli, and the continuation of the circuli into the upper section of the apical pole, where they meet in an acute angle. The extreme posterior margin of *Goudkoffia* may be smooth, whereas in *Natlandia* the entire apical region is free of circuli, showing reticulations in places. *Goudkoffia* is probably a salmon-like fish, smaller and more delicate than the preceding form. All living salmon scales are unlike *Goudkoffia* in lacking an apical pole with angular circuli, although a number of forms have uninterrupted concentric circuli. Some of the living Anacanthini show scales similar to the fossil; all of these are degenerate small scales, much thinner than the specimen described here. Anacanthini have not been described from the Cretaceous.

ORDER INIOMI

Family CHLOROPHTHALMIDAE

? **Sardinioides californicus,** n. sp.

(Text figures 6, 7)

Type. No. 10313, Calif. Inst. Tech. Vert. Pale. Coll. Scale 5 mm. long by 6 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6287 to 6292 feet. Moreno formation.

Description. Type a comparatively large, thin scale, irregularly twisted and bent in rock. Part of ventral edge missing. Other, and for the most part smaller, specimens from the same locality and horizon measure (length and depth, in millimeters): 3 by 2.5, 2 by 1.9, 2.5 by 1.9, 4 by 2; lateral-line scales, probably of same species, measure 2 by 2.5, 2.2 by 2.5 mm.; and a single scale, probably of a related species,

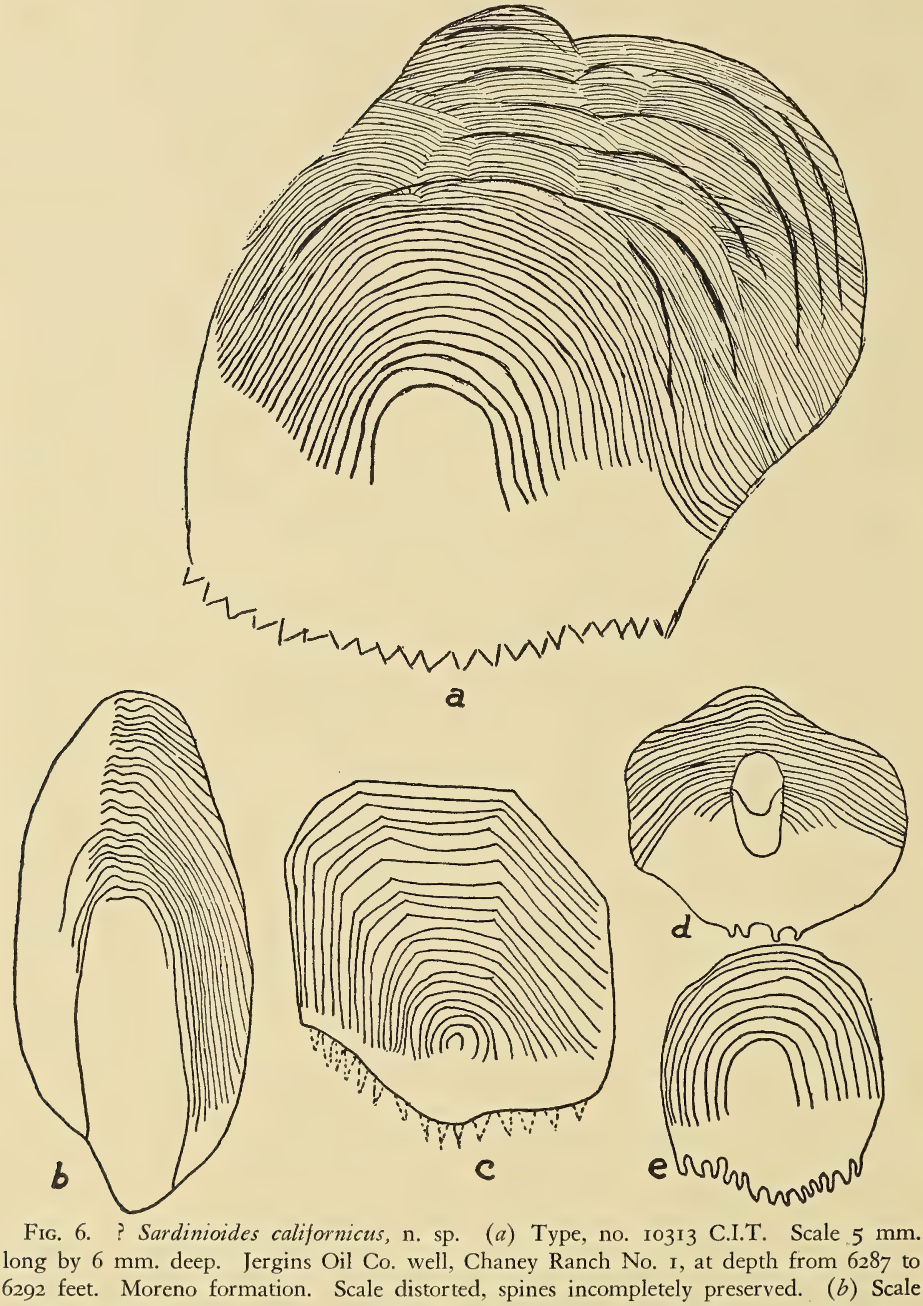


Fig. 6. ? *Sardinioides californicus,* n. sp. (*a*) Type, no. 10313 C.I.T. Scale 5 mm. long by 6 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6287 to 6292 feet. Moreno formation. Scale distorted, spines incompletely preserved. (*b*) Scale 4 mm. long by 2 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6287 to 6292 feet. Moreno formation. (*c*) Scale 2 mm. long by 1.9 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6287 to 6292 feet. Moreno formation. (*d*) Scale 2 mm. long by 2.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6605 to 6608 feet. Moreno formation. (*e*) Scale 3 mm. long by 2.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6287 to 6292 feet. Moreno formation.

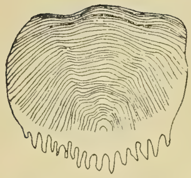


FIG. 7. ? *Sardinioides* sp. Scale 2.2 mm. long by 3 mm. deep. Pure Oil Co. well, Chowchilla No. 1, at depth from 4629 to 4636 feet. Panoche formation.

from the Pure Oil Co. well, Chowchilla No. 1, at depth from 4629 to 4636 feet, measures 2.2 by 3 mm. Basal region without definite folds; circuli in some scales concentric, evenly rounded, in others showing definite curvature in 2 or 3 diagonal lines through basal part. Circuli restricted to basal part of scale, forming fine lines, characteristically separated by large distances in center of scale and more and more close-set toward outer margin. Circuli quite dense at basal margin of type. In figured scales (fig. 6) distances do not vary much. In the type there are 13 circuli in 1 mm. distance at center of scale, 32 at basal margin. In the scale shown in figure 7 there are 22 circuli in 1 mm. distance. Apical pole smooth, with one row of serrations on its margin; these are more or less flat, not well formed spines, and form a direct continuation of scale; number and shape of serrations irregular. Lateral-line scales are typical for family and for the Iniomi in general: very fine circuli, more or less transverse, restricted to basal border of scale, those around center of scale shortening rapidly; circuli directed obliquely apicad at dorsal and ventral borders; serrations few and usually in middle of apical border.

Occurrence. The scales described above were found occasionally at several horizons, nowhere in great numbers. Some occur in the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6287 to 6292 feet. Lateral-line scales probably of the same species occur in the same well at depth from 6605 to 6608 feet, and in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4960 to 4965 feet. A single scale was found in the Pure Oil Co. well, Chowchilla No. 1, at depth from 4629 to 4636 feet.

Relationships. All scales described above belong to the order Iniomi, which includes a wholly bathyal group of fishes. All these scales were found in small numbers at different horizons, and it is doubtful if they all belong to one species. The single scale found in the Pure Oil Co. well, Chowchilla No. 1, probably belongs to a different species and may even belong to another family of the order, the Myctophidae, or lantern fishes. All the remaining scales described probably belong to one species. They show the typical characters of the Chlorophthalmidae, with widely spaced circuli around the nucleus and very fine circuli at the basal margin in the larger scales, the circuli being evenly rounded in some scales, curved to indistinct folds in others, and the apical border having one row of serrations. Also the lateral-line scales (fig. 6*d*) are typical of *Chlorophthalmus.* The scales in this genus show considerable variation in different parts of the body, and an extreme type is represented in figure 7. The latter scale, however, seems to have stronger serrations at the apical pole, and the circuli around the nucleus are not so widely spaced. Characteristic of all these deep-water types of the Iniomi is the fineness of the circuli, representing fine, shallow grooves, quite different from the coarse, elevated ridges seen in scales of some of the other families.

Fishes of the order Iniomi are found abundantly in Cretaceous deposits of other parts of the world. Nearly all of these have been attributed to the Myctophidae (= Scopelidae). Woodward, however, (1902, p. 33), although assigning the genus *Sardinioides* von der Marck to the Scopelidae, demonstrates its close relationship to the Chlorophthalmidae, *Chlorophthalmus* and *Aulopus.* The scales found in the Moreno of California certainly show a relationship to *Chlorophthalmus,* and it is not unlikely that the California form is identical with *Sardinioides,* to which it is provisionally assigned. *Sardinioides* is common in the Upper Cretaceous of Westphalia, Mount Lebanon, and the English chalk. No doubt the Iniomi were represented by a number of families in the Upper Cretaceous. The genera *Sardinius, Leptosomus,* and *Rhinellus* are known from Cretaceous deposits of the United States.

ORDER ANACANTHINI

? Superfamily MACROUROIDEA

Rankinia macrouriformis, n. g. and n. sp.

(Text figure 8)

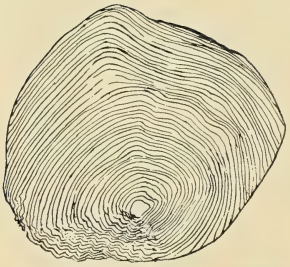


Fig. 8. *Rankinia macrouriformis,* n. g. and n. sp. Type specimen, no. 10314 C.I.T. Scale 4 mm. long by 4.2 mm. deep. Pure Oil Co. well, Chowchilla No. 1, at depth from 5010 to 5048 feet. Panoche formation. Dorsoapical part, bent upward in rock. (Drawn from photograph.)

Type. No. 10314, Calif. Inst. Tech. Vert. Pale. Coll. Scale 4 mm. long by 4.2 mm. deep; slightly bent in the rock.

Type locality. Pure Oil Co. well, Chowchilla No. 1, at depth from 5010 to 5048 feet. Panoche formation.

Description. Scales quadrangular to rounded, delicate. No definite folds in basal part of scale. Circuli bent in laterobasal diagonals and through median line, but not very prominently; otherwise basal circuli evenly rounded and concentric. Nucleus little below center of scale (type shown in figure 8 is shortened in apical part, since apicodorsal part is bent upward into the rock). Circuli are fine lines, 26 in 1 mm. distance in center of scale, distances between circuli much wider than width of circuli. Circuli in apical pole continuous with basal ones, but divided in a series of acutely angled serrations. Apical border serrated following the lines of the outermost circuli.

The new genus is named for Mr. Wilbur D. Rankin, paleontologist, of Los Angeles, California.

Relationships. Rankinia is a well defined and characteristic type of scale. As yet no recent scale has been seen which agrees with it. It seems likely that the fossil belongs to the Anacanthini, and it is tentatively referred to the macrouriform fishes. Delicate cycloid scales of the type of *Rankinia,* with circuli in part concentric and in part with irregular zigzag patterns, are found in this group among the Bathygadinae, but the circuli in scales of the latter group seem to be directed perpendicularly to the apical and basal borders. Many macrourid fishes show a series of serrations of the circuli in the apical pole and concentric curved basal circuli, showing more or less distinctly marked angles in the diagonals of the scale, like those seen in *Rankinia;* but they all either are ctenoid or at least show strong ribbing. It is quite possible that *Rankinia* is an extinct ancestor of some group of the Anacanthini, possibly intermediate between Gadoidea and Macrouroidea. For the present, however, there is no certain character to prove this relationship. All the Recent fishes mentioned above are deep-sea forms.

ORDER BERYCOMORPHI

Family HOLOCENTRIDAE

Paraberyx californica, n. g. and n. sp.

(Plate 1, figures 5, 6; text figure 9)

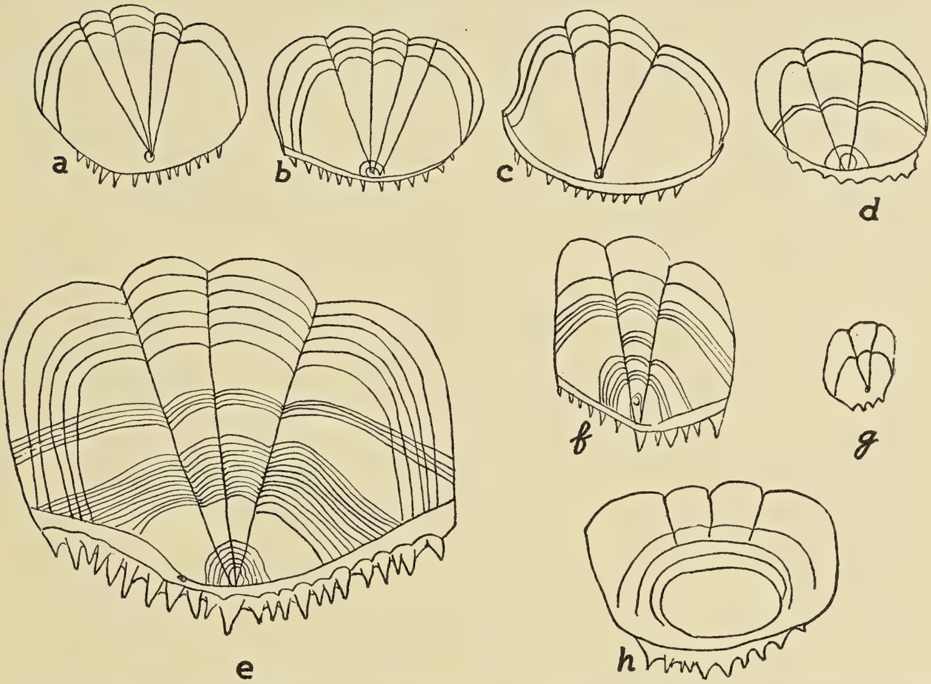


Fig. 9. *Paraberyx californica,* n. g. and n. sp. (*a*) Coarse side of scale 3.1 mm. long by 4 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. (*b*) Smooth side of scale 3 mm. long by 3.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7086 to 7095 feet. Panoche formation. (*c*) Smooth side of scale 3.1 mm. long by 3.9 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7077 to 7086 feet. Panoche formation. (*d*) Mold of smooth side of scale 2.5 mm. long by 3 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. (*e*) Type specimen, no. 10310 C.I.T. Coarse side of scale 2.9 mm. long by 3.2 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. (*f*) Cotype, no. 10311 C.I.T. Scale 2 mm. long by 2.1 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7095 to 7104 feet. Panoche formation. (*g*) Coarse side of scale 1.5 mm. long by 1 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. (*h*) Mold of smooth side of scale 3.5 mm. long by 4.8 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7077 to 7086 feet. Panoche formation.

Type. No. 10310, Calif. Inst. Tech. Vert. Pale. Coll. Scale 2.9 mm. long by 3.2 mm. deep.

Type locality. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation.

Cotype. No. 10311, Calif. Inst. Tech. Vert. Pale. Coll. Scale 2 mm. long by 2.1 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7095 to 7104 feet.

Description. Scales small, oval to semirounded, larger scales fan-shaped, very small ones quadrangular. Average scale sizes (length and depth, in millimeters): 3.9 by 5, 3.9 by 4, 3.2 by 4, 3.1 by 3.9, 3 by 3.1, 2.1 by 3, 1.9 by 2, 1.5 by 1. Two to 3 very pronounced folds pass through basal part of scales, deeply scalloping the basal margin; these extend almost through entire scale to subapical nucleus. Circuli coarse and close-set, 30 in 1 mm. distance in central part of type, 28 in apical region of a larger scale, 38 toward basal margin in the same specimen. Basal circuli transverse, slightly curved, ending at ventral and dorsal margin of scale; circuli more curved toward apical region, most central ones form half circle around nucleus and end near apical border. Marginal ends of circuli sometimes straight, generally curved upward (pl. 1, fig. 5). All circuli follow curves of central folds; course of circuli in basomarginal region variable, following exterior shape of scale. In smaller scales, only the stronger curved central circuli present. Nucleus very low, almost on apical border. Apical part restricted to posterior border, which is smooth and free of circuli, equipped with a row of strong, compact spines. Apical margin corrugated where spines are attached. Apical margin thickened with an elevated rim on smooth side of scale (pl. 1, fig. 5; text fig. 9*b, c*). Outer margin of scale folded concentrically with 2 or 3 or more folds; these folds partly due to annual growth of scale, folding evidently increased by compression of scale in rock. Dividing line of vertical folds indented on smooth side of scale (pl. 1, fig. 5). Atypical scales of the form show center free from circuli and surrounded by large oval lines, the folds marked only in marginal basal region.

Occurrence. This scale is extremely abundant in the horizons in which *Driverius cretaceus* occurs, that is, mainly in the uppermost strata of the Panoche formation in the Big Panoche Creek area. Numerous specimens have been preserved in cores of the Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7086 to 7141 feet; and in the Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4886 to 5065 feet.

Relationships. *Paraberyx* has the typical structure seen in Cretaceous berycomorph fishes, with the subapical nucleus, a small number of strong vertical folds extending through scale toward nucleus, and compact spines. Numerous berycomorph fishes have been described from Cretaceous deposits, and pectinated scales of similar structure are known from the Cthenothrissoidea. Several other genera, for example, *Pseudoberyx* Pictet and Humbert, referred to the Clupeidae by some authors, are also said to have pectinated scales of similar type. The scales of *Paraberyx* are small but show the robust structure of adult fish. Indications of annual rings and folding of the exterior margin of the scale seem to show ages of several years in most cases. The scales undoubtedly belong to a small genus with bercycomorph relationship. They do not show a broad, thickened apical region, only the exterior margin of the apical pole being elevated. The apical spines are almost completely without keels. The scales are, therefore, not closely related to *Beryx* or *Haplopteryx*. *Ctenothrissa* also has the apical pole thickened through a larger area. Shape and attachment of the apical spines are reminiscent of the Holocentridae, but they are not at all or only slightly extended in apical keels. Holocentric fishes are the most primitive Berycomorphi, as Cockerell states (1919, p. 187), and *Paraberyx* is evidently related to this group. Hussakoff (1929) described a small holocentrid form from the Niobrara of Kansas, namely, *Kansius sternbergi.* The Californian form may be a related type. For the time being it does not seem possible to attribute the Californian scale to a distinct genus of the Berycomorphi. This order was well developed in the Cretaceous and showed greater diversity of type than it does today. The Percomorphi have probably taken the place of the Berycomorphi in some habitats. The recent Berycomorphi are to a large extent deep-water forms, the Holocentridae abounding in coral reefs and other rocky parts of warm seas. *Paraberyx* evidently was a shallow-water form, as is indicated by the coarse structure of the scale and its relationships.

Family TRACHICHTHYIDAE

Rothwellia trachichthyiformis, n. g. and n. sp.

(Text figure 10)

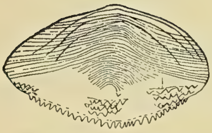


FIG. 10. *Rothwellia trachichthyiformis,* n. g. and n. sp. Type, no. 10312 C.I.T. Scale 2.5 mm. long by 4 mm. deep. Pure Oil Co. well, Chowchilla No. 1, at depth from 4955 to 4974 feet. Panoche formation.

Type. No. 10312, Calif. Inst. Tech. Vert. Pale. Coll. Scale 2.5 mm. long by 4 mm. deep.

Type locality. Pure Oil Co. well, Chowchilla No. 1, at depth from 4955 to 4974 feet. Panoche formation.

Description. Scale oval, much deeper than long, and evidently from the midlateral series on the fish. Scale quite delicate, broken or fragmentary. Basal part with slightly curved circuli, but not marked by distinct folds. Circuli present in basal part only, comparatively fine shallow grooves, at some distance apart; about 24 in 1 mm. distance through median line of scale. Circuli nearest to basal margin transversely rounded, ending in dorsal and ventral margins of scale. Distance between adjacent circuli widening toward margin of scale; this is especially true for lowermost circuli, which end much more obliquely in dorsal or ventral margin. Circuli nearing center of scale curve around nucleus; these are short and end free toward apical pole. Apical region with several rows of staggered broad, flat spines, upper rows inserted above bases of next lower row. One row of fine spines along apical margin. Basal margin folded concentrically several times.

The new genus is named for Mr. W. Thomas Rothwell, Jr., paleontologist of the Richfield Oil Corporation, California.

Discussion. Only one scale of this delicate form has been found. The impression of the smooth side is complete; the scale is fragmentary in places. It undoubtedly belongs to a berycomorph form and is probably nearly related to the Trachichthyidae of today, a family of the deep-water Berycomorphi. Woodward (1902, p. 29) described the genus *Trachichthyoides* from the English chalk; it resembles *Trachichthys* and *Gephyroberyx.* The delicacy of the scale and its structure indicate that *Rothwellia* lived in at least a bathyal habitat. In the Trachichthyidae the length-depth proportions of the scales are quite variable, the mid-lateral scales being deepest. It is likely that the Cretaceous genus showed similar differences in shape of its scales, and that the scale described here belongs to the lateral series.

ORDER PERCOMORPHI

SERIES CARANGIFORMES

Incertae sedis

(Text figure 11)

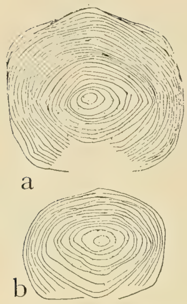


FIG. 11. Incertae sedis (Carangoidea?) (*a*) Scale 2.8 mm. long by 3 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6292 to 6297 feet. Moreno formation. (*b*) Scale 1.7 mm. long by 2 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6437 to 6443 feet. Moreno formation.

Description. Scales quadrangular to rectangular; length and depth (in millimeters): 2.8 by 3.2, 2.2 by 2.8, 2 by 2, 1.5 by 2. Circuli concentric; those around focus widely spaced, irregular in shape, sometimes bent in places. Circuli in outer two-thirds of scale closer and more regularly concentric. Apical pole evidently lost; it may have been smooth and less resistant. Ornamentation in form of tubercles or very short lines in middle of scale and toward apical pole.

Discussion. Small scales like those described above and generally pyritized are found in the Moreno formation. All are somewhat distorted and incomplete. They remind one of the living Carangidae. The scales are thicker than the degenerate carangoid scales found in modern forms. The circuli are more irregularly arranged, and reticulations are present. Evidently these scales are less resistant to wear than the larger specimens, and are preserved only under favorable conditions, if pyritized. They occur with *Natlandia ornata,* and may be atypical scales of that form. The circuli, however, are arranged differently, and become finer toward the outer margin. Carangiformes have been described from Cretaceous deposits elsewhere, and it is quite possible that the scales here described belong to this order.

ANALYSIS OF PISCINE ASSEMBLAGES

The following fish forms have been identified thus far in the Upper Cretaceous of California:

A. Large skeletal fragments from the Moreno formation of the Panoche Hills

Protosphyraena sp.
Pachyrhizodus sp.
Enchodus sp.
Vertebrae of large selachians

B. Scales from subsurface sections of the Moreno formation in Panoche Creek and in the Firebough area

	Rare, poorly preserved	Moderately abundant	Abundant, well preserved
Corax sp.	+	?	..
Erythrinolepis cf. chicoensis	..	+	..
Holcolepis angulatus	..	+	..
Holcolepis nodulatus	..	+	..
Laimingia plicata	..	..	+
Helmintholepis sp.	+	..	..
Kleinpellia morenoensis	..	..	− +
Natlandia ornata	..	..	+
Goudkoffia delicata	..	+	..
? Sardinioides californicus	..	+	..
Carangoidea	..	+	..

C. Scales from subsurface sections of uppermost Panoche formation (shale deposits) in the Panoche and Firebough districts

	Rare, poorly preserved	Moderately abundant	Abundant, well preserved
Erythrinolepis cf. chicoensis	+	..	..
Laimingia plicata	..	..	+
Kleinpellia morenoensis	+	..	..
Driverius cretaceus	..	..	+ +
Natlandia ornata	..	+	..
Goudkoffia delicata	+	..	..
? Sardinioides californicus	+	..	..
Paraberyx californicus	..	..	+ +

D. Scales from subsurface sections of the Panoche formation in the Chowchilla district (mostly sandy deposits and sandy shales)

Laimingia plicata	+	..	..
Kleinpellia morenoensis	+	..	..
Ichthyodectes sp	+	..	..
Bramlettia chicoensis	..	+	..
? Sardinioides sp.	..	+	..
Rankinia macrouriformis	..	+	..
Rothwellia trachichthyiformis	..	+	..

The fish fossils described here are for the most part new genera and species. This is to be expected in a geologic section such as that represented by the thick sequence of strata of the California Upper Cretaceous, which is almost unexplored for fish. Most of the new types are established on the basis of fish-scale characters, and it has been found possible, in almost all cases, to make a reliable identification of the families and genera, and to determine their relationships. Two species apparently belong to kinds of fish found previously in California, namely, *Erythrinolepis chicoensis* Cockerell and *Bramlettia chicoensis* (Cockerell). The scales of three additional genera agree with forms found commonly in other Cretaceous deposits, namely, *Holcolepis* ?, *Sardinioides,* and *Ichthyodectes.* The scales of most of the genera of Cretaceous fish that have been described from skeletal remains are not known. This is particularly true for the Cretaceous fish of North America. Later it may be possible to show that some of the genera herein named on the basis of scales belong to fish already described from skeletal remains.

The Cretaceous forms listed above can be grouped in different assemblages, according to their place of occurrence and their habitat. All these groups indicate faunas of coastal water, and none can be regarded as living in a true deep-sea habitat.

The geologic sections in the Panoche Creek and Firebough districts show two characteristic fish zones at different horizons: The upper fish zone is characterized by remains from the Moreno formation as listed under A and B (see above). The fish types inhabited a coastal sea and were evidently irregularly distributed over a large area. This is true for *Protosphyraena, Pachyrhizodus, Corax, Holcolepis, Kleinpellia,* and the Carangoidea; *Enchodus* may have preferred slightly deeper water. *Erythrinolepis,* as stated by Cockerell, may be related to living fresh-water forms from South America, but it was evidently a marine type in the Cretaceous. *Laimingia* is nearly related to *Elops,* a fish genus that occurs now in near-shore waters and lagoons, and occasionally ascends rivers. *Natlandia* and *Goudkoffia* are related to the salmon, which are anadromous fishes today. ? *Sardinioides* is the only fish of these strata having a bathyal habitat, and scales of it occur infrequently. Most of the scales in section B are pyritized. The deposit undoubtedly was laid down in the neritic region of a coastal sea, with the fossils irregularly scattered over a large area of the sea bottom. Fish scales are not everywhere present in the section. In the Jergins Oil Co. well, Chaney Ranch No. 1, they occur at depths from 6206 to 6306 feet and from 6231 to 6988 feet. In the Western Gulf Oil Co. well, Lillis Welch No. 1, scales occur at depths from 3715 to 4792 feet.

A decided change occurs in the fish fauna at a deeper horizon in the stratigraphic succession. These strata have been determined by some students of foraminifera as lowermost Moreno in age and by others as uppermost Panoche. The latter determination is accepted in the present paper. The lower fish zone is very characteristic and occurs in a comparatively narrow stratigraphic interval in the section. The change in the fishes is shown best by the great abundance of two forms, *Driverius cretaceus* and *Paraberyx californicus.* Of these two, *Driverius* is closely related to a group of herrings now restricted to warm seas and generally known from coastal bays near river outlets. *Paraberyx* belongs in the group of shallow-water berycoids. *Laimingia* and *Natlandia* are quite abundant, and both forms may well be found at the mouth of a river, and therefore be deposited in a near-shore accumulation. None of the larger forms, not even *Holcolepis,* has been found as yet in the lower fish zone. They evidently are rare or absent here. Thus, the assemblage suggests a near-shore deposit accumulating apparently in the proximity of a river outlet. All the forms that are present could have lived in this kind of environment. Immediate burial of the assemblage did not occur at the place of accumulation. All the fish are completely decayed and few remains except scales are preserved. Since scales are small and light, they may have been held in suspension for some time and may have been transported by currents. Their ultimate deposition probably occurred in a deeper and quieter part of the sea. They are preserved in an organic slaty dark shale, brittle and with even splitting surfaces. The lower fish zone was found in the Jergins Chaney Ranch well at depths from 7003 to 7144 feet, and in the Western Gulf Lillis Welch well at depths from 4886 to 5242 feet.

The stratigraphic succession found in the Panoche formation of the Chowchilla region shows entirely different occurrences of fish remains. Fish forms are very rare, especially in the sandy parts, and are hardly abundant enough to provide data from which to draw many conclusions. In the subsurface interval from 4629 to 5083 feet in the Pure Oil Co. well, Chowchilla No. 1, scales were found at several horizons. Among these some are rather significant. The better-preserved scales, such as an Iniomi, *Rothwellia, Ichthyodectes,* and probably *Rankinia,* represent types living in deeper water. The strata from 4955 to 5048 feet in the section, although quite sandy, represent a bathyal deposit, and the region of accumulation was connected with the open sea.

The antiquity of the deep-sea fish fauna has been discussed by Woodward (1898). Many types related to deep-sea forms of today existed in Cretaceous times. Such deep-water types as the Iniomi and certain Berycomorphi were widely distributed. Some that are found in Cretaceous deposits may have been in a stage of transition between habitats of different bathymetric depth. Woodward (1911) states that some of the types show a more calcified skeleton than is usual in bathyal and abyssal fishes. Others were undoubtedly deep-water forms (*Tomognathus,* Woodward, 1936). There is not much doubt that the delicate scales listed above, for example, *Sardinioides* and the trachichthyiform *Rothwellia,* came from typical bathyal fish, because of their great similarity to scales of living types. The relationship of *Rankinia* is not well enough known to justify conclusions. The extinct *Ichthyodectes* is also considered a bathyal fish.

A warm climate is indicated by the majority of California Cretaceous fish. This is true for the Elopidae, Albulidae, and Holocentridae. It is especially true for *Driverius,* which seems to be related to forms now restricted to warm waters and largely distributed through the tropics. On the other hand, more or less distant ancestors of the Salmonoidea are well represented in the North American Cretaceous deposits. The California fish *Natlandia* does not seem to be far removed from the living forms. Salmonoidea are characteristically northern in habitat. This group evidently was not well established in Upper Cretaceous time, and its habitats may not have conformed to those of Recent types. Evidently *Natlandia* was not anadromous as most of the living salmons are. The Californian form, as yet known only from its scale, would represent the earliest known salmon, should it prove to be a true member of this family.

Upper Cretaceous fishes are known from a number of localities distributed over the world. Some of these localities have yielded quite diversified faunas, and progressive ages can be recognized. Upper Cretaceous faunas found in the Gabon Basin in Africa (Weiler, 1922; Arambourg and Schneegans, 1935) seem to correspond to strata of Brazil (Jordan, 1923; Jordan and Branner, 1908; Maury, 1930, 1936) and may possibly be of Cenomanian age or older. The deposits of the English chalk are of Turonian age. The strata of Westphalia and of Mount Lebanon, Syria (Woodward, 1942*a*) are Upper Senonian, the latter being slightly younger than the former. Danian fishes are found in Scandinavia (Davis, 1890) and in Persia (Priem, 1908), but neither one of these assemblages is well known. Still younger in the Cretaceous are the deposits of the Montian chalk of northern France (Priem, 1898); and the Lameta beds of India (Woodward, 1908) may be of earliest Tertiary age.

There are many indications that the Moreno and Panoche fishes occur in a late stage of the Cretaceous. The Ganoidea are represented only by *Protosphyraena.* This is the latest and largest pachycormid, common in the Upper Cretaceous of Europe and North America, and probably present also in Egypt and Patagonia. The Albulidae are represented by a form nearly related to Recent types, and not found anywhere else. The Elopidae are represented by two species of *Holcolepis,* a genus found commonly in the English chalk, Westphalia, the Mount Lebanon deposits, and the North American interior basins. Likewise, *Laimingia* is a form much more closely related to the living *Elops* and farther developed than *Rhacolepis,* a fish of frequent occurrence in the Brazilian Cretaceous. Two true clupeids are present in California; such types are not found in the English chalk, nor in the Central American deposits, but a number of clupeids are abundant in Syria. *Diplomystus,* however, the double-armored herring, which may have had scales of clupeid type, was already present in the Lower Cretaceous of Brazil. Also salmon are represented by a form that seems to be more closely related to present-day members of this group than are those found anywhere else in the Cretaceous.

Fishes like *Pachyrhizodus, Enchodus,* and *Ichthyodectes* or nearly related genera are of common occurrence in all the better-known Cretaceous deposits. Iniomi also occur in great abundance and variety throughout Cretaceous formations. Berycomorphi, also commonly found in Cretaceous deposits, are represented in California by a small genus and a specialized form belonging to one of the deep-sea families. The large-scaled Berycomorphi, for example *Hoplopteryx,* so common in other Upper Cretaceous deposits, have not been found as yet in California. Cockerell (1919) states that the Berycomorphi are absent from the American Cretaceous of the interior regions. The acanthopterygians, or more advanced fishes, are represented in the Moreno and Panoche deposits of California by the Berycomorphi and generalized forms that are tentatively referred to the Carangoidea. No true Percomorphi are present.

The differences between the fish faunas of the various known Upper Cretaceous deposits are due only in part to changes occurring in the course of geologic time. Geographical distribution and differences in facies also account for some of the dissimilarity in the assemblages. The Californian deposits, with typical clupeids, advanced elopids, abundant albulids and Salmonoidea, and with the rare occurrence of ganoids, are certainly not older than the Senonian and are probably more advanced than that stage. Absence of true percomorph scales suggests an earlier stage than Uppermost Cretaceous, when these types of fishes are known to have been present. The first true percomorph fishes are found in deposits of the Montian chalk of France, and in the Lameta beds of India. Some early and primitive percomorph fishes are known to occur in the Upper Senonian beds of Mount Lebanon (Woodward, 1942*a,* 1942*b*). These latter seem to have smooth and cycloid scales of primitive character, not unlike those described above.

Bibliography

Arambourg, C., and D. Schneegans. 1935. Poissons fossiles du bassin sédimentaire du Gabon. Ann. Paléontol., vol. 24, pp. 139–160.

Cockerell, T. D. A. 1919. Some American Cretaceous fish scales. U. S. Geol. Surv. Prof. Paper 120, pp. 165–188.

Cope, E. D. 1875. Cretaceous vertebrata. Rept. U. S. Geol. Surv. Terr., vol. 2.

Cope, E. D. 1878. Descriptions of fishes from the Cretaceous and Tertiary deposits west of the Mississippi river. Bull. U. S. Geol. Surv. Terr., vol. 4.

Davis, J. W. 1887. The fossil fishes of the chalk of Mt. Lebanon in Syria. Trans. Roy. Dublin Soc., ser. 2, vol. 3, p. 584.

——— 1890. On the fossil fish of the Cretaceous formations of Scandinavia. *Ibid.,* vol. 4, pp. 417–427.

Fritsch, A. 1878. Die Reptilien und Fische der böhmischen Kreideformation. Prague.

Geinitz, H. B. 1868. Die fossilen Fischschuppen aus dem Planerkalke in Strehlen. Dresden, Gesellsch. Natur und Heilkunde.

Hay, O. P. 1903*a*. On certain genera and species of North American Cretaceous actinopterous fishes. Bull. Amer. Mus. Nat. Hist., vol. 19, pp. 1–95.

——— 1903*b*. On a collection of Upper Cretaceous fishes from Lebanon, Syria. Bull. Amer. Mus. Nat. Hist., vol. 19, pp. 395–452.

——— 1929. Second bibliography and catalogue of the fossil vertebrata of North America. Carnegie Inst. Wash. Pub. 390.

Hussakoff, L. 1929. A new teleostean fish from the Niobrara of Kansas. Amer. Mus. Novit. No. 357, pp. 1–4.

Jordan, D. S. 1923. Peixes cretaceos. Monographias Serv. geol. e mineral. do Brasil, vol. 3, pp. 1–97.

——— and J. C. Branner. 1908. The Cretaceous fishes of Ceara, Brazil. Smithsonian Misc. Coll., vol. 52, pp. 15–25.

Marck, W. von der. 1863. Fossile Fische, Krebse und Pflanzen aus dem Plattenkalke der jüngsten Kreide in Westphalien. Palaeontographica, vol. 2, pp. 1–83.

——— 1876. Neue Beitraege zur Kenntnis der fossilen Fische und anderer Tierreste aus der jüngsten Kreide Westphaliens. Palaeontographica, vol. 22, pp. 55–74.

——— and A. Schlueter. 1865–1868. Neue Fische und Krebse aus der Kreide von Westphalen. Palaeontographica, vol. 15, pp. 269–305.

Martin, G. H. 1920. *Anguillavus hackberryensis,* a new species and genus of fish from the Niobrara Cretaceous of Kansas. Sci. Bull. Univ. Kans., vol. 13, no. 7, p. 95.

Maury, J. C. 1930. O Cretaceo da Parahyba do Norte. Monographias Serv. geol. e mineral. do Brasil, vol. 8, pp. 80–105.

—— 1936. O Cretaceo de Sergipe. Monographias Serv. geol. e mineral. do Brasil, vol. 2, pp. 49–57.

McClung, E. E. 1926. *Martinichthys* a new genus of Cretaceous fish from Kansas. Proc. Amer. Philos. Soc., vol. 65, pp. 20–26.

Pictet, F. J., and A. Humbert. 1866. Nouv. recherches poissons foss. Mt. Lebanon. Arch. sci. Génève, vol. 26.

Priem, F. 1898. Sur la faune ichthyologique des assises Montiennes du Bassin de Paris. Bull. Soc. géol. de France, ser. 3, vol. 26, pp. 399–412.

——— 1908. Mission de Morgan. Poissons fossiles de Perse. Paris.

Weiler, W. 1922. Die Fischreste aus den bituminösen Schiefern von Ibando bei Bata, Spanisch Guinea. Paläontol. Ztschr., vol. 5, pp. 148–160.

Woodward, A. S. 1898. The antiquity of the deep-sea fish-fauna. Nat. Sci., vol. 12, pp. 257–260.

——— 1907. Notes on some Upper Cretaceous fish remains from the provinces of Sergipe and Pernambuco, Brazil. Geol. Mag., ser. 5, vol. 4, pp. 193–197.

WOODWARD, A. S. 1908. On some fish remains from the Lameta beds at Dongargaon, Central Provinces, India. Paleontol. Indica, n. s., vol. 3, no. 3.

——— 1902–1911. The fishes of the English chalk. Monogr. Palaeontol. Soc. London, vols. 56–65.

——— 1936. On *Tomognathus,* a teleostean fish from the English chalk. Ann. Mag. Nat. Hist., ser. 10, vol. 17, pp. 305–306.

——— 1942*a*. On some new and little known Upper Cretaceous fishes. Ann. Mag. Nat. Hist., ser. 11, vol. 9, no. 56, pp. 537–568.

——— 1942*b*. The beginning of the teleostean fishes. Ann. Mag. Nat. Hist., ser. 11, vol. 9, no. 60, pp. 902–912.

PLATES

PLATE 1

FIG. 1. *Kleinpellia morenoensis,* n. g. and n. sp. Type, no. 10304. Scale 7.2 mm. long by 7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6595 to 6605 feet. Moreno formation. Coarse side of scale, pyritized. (See also text fig. 3.)

FIG. 2. ? *Pachyrhizodus* sp. Scale 20.5 mm. long by 23 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4954 to 4960 feet. Moreno formation.

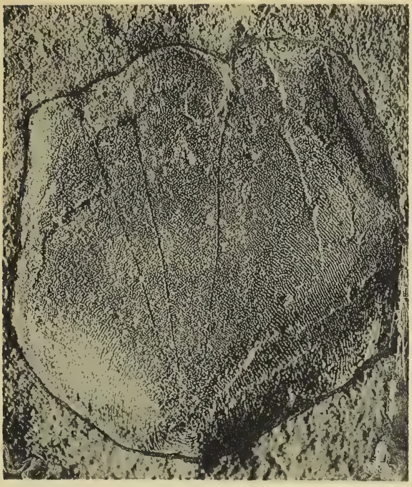
FIG. 3. *Laimingia plicata,* n. g. and n. sp. Type, no. 10307. Scale 3.2 mm. long by 4.1 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4436 to 4451 feet. Moreno formation. Coarse side of scale, pyritized.

FIG. 4. *Laimingia plicata,* n. g. and n. sp. Scale 4 mm. long by 4.1 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6605 to 6608 feet. Moreno formation. Coarse side of scale, smooth side preserved in part of apical region.

FIG. 5. *Paraberyx californica,* n. g. and n. sp. Scale 3.1 mm. long by 3.9 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth of 7086 feet. Panoche formation. Smooth side of scale.

FIG. 6. *Paraberyx californica,* n. g. and n. sp. Type, no. 10310. Scale 2.9 mm. long by 3.2 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. Coarse side of scale.

Calif. Inst. Tech. Vert. Pale. Coll.



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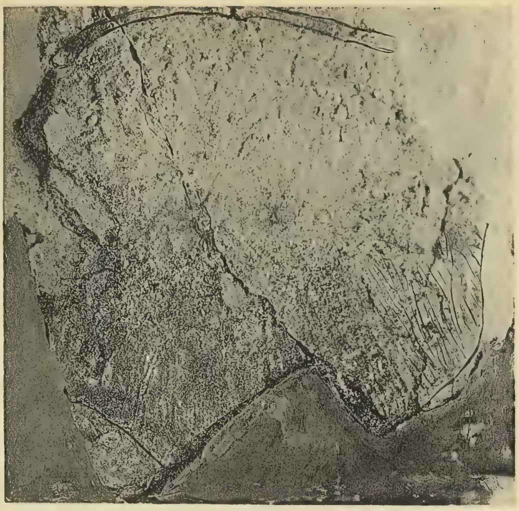

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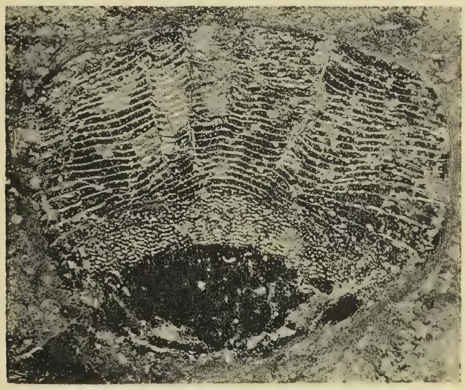

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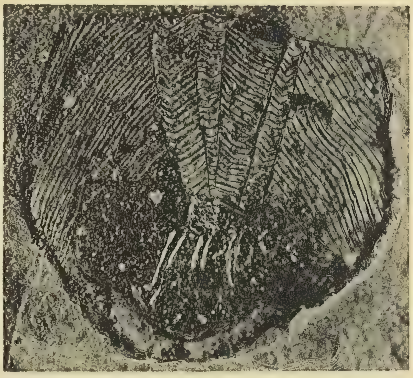

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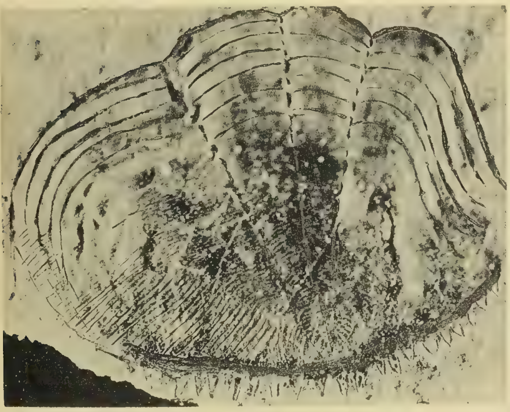

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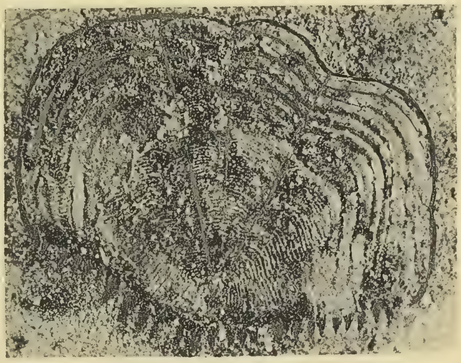

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PLATE 2

FIG. 1. *Natlandia ornata,* n. g. and n. sp. Lateral-line scale tentatively referred to this species, 7 mm. long by 6.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6451 to 6459 feet. Moreno formation. Coarse side of scale, pyritized.

FIG. 2. *Goudkoffia delicata,* n. g. and n. sp. Type, no. 10309. Scale 4.2 mm. long by 4 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. Coarse side of scale.

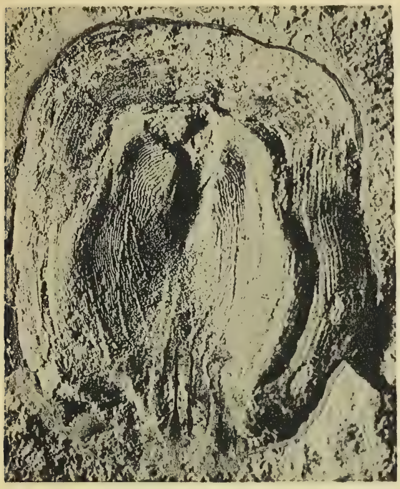
FIG. 3. *Natlandia ornata,* n. g. and n. sp. Counterpart of type, no. 10308. Scale 7.7 mm. long by 5.2 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6507 to 6514 feet. Moreno formation. Coarse side of scale, pyritized.

FIG. 4. *Holcolepis nodulatus,* n. sp. Type, no. 10333. Scale 10 mm. long by 13 mm. deep. Western Gulf Oil Co. well, Lillis Welch No. 1, at depth from 4387 to 4396 feet. Moreno formation. Coarse side of scale.

FIG. 5. *Erythrinolepis* cf. *chicoensis* Cockerell. Scale 12 mm. long by 12.5 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. Mold of smooth side of scale; actual scale preserved in places.

FIG. 6. *Holcolepis angulatus,* n. sp. Type, no. 10334. Scale 12.4 mm. long by 14 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6654 to 6663 feet. Moreno formation. Mold of coarse side of scale; small part of actual scale, which is pyritized, present at apical pole.

Calif. Inst. Tech. Vert. Pale. Coll.



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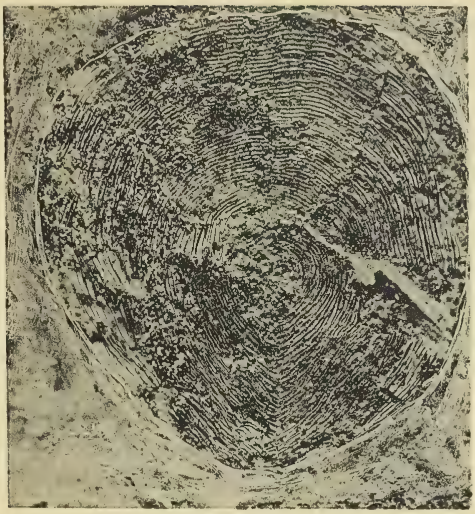

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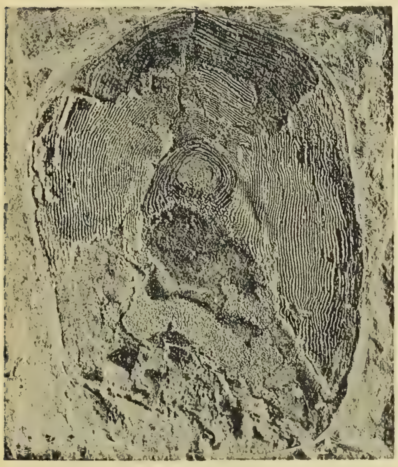

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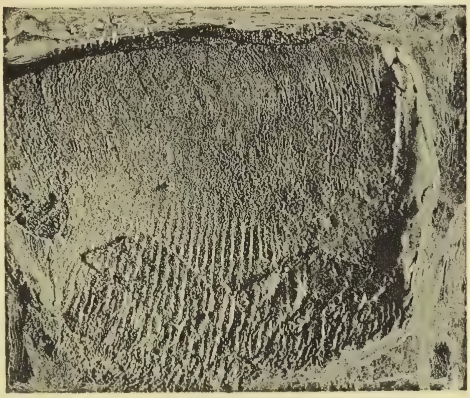

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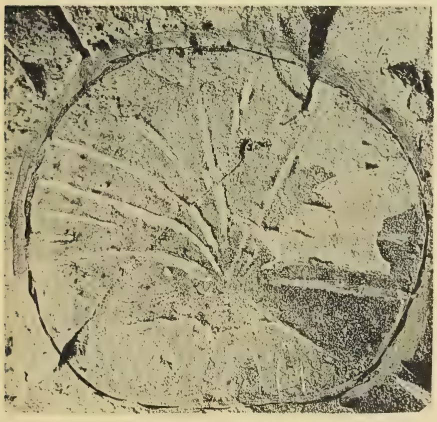

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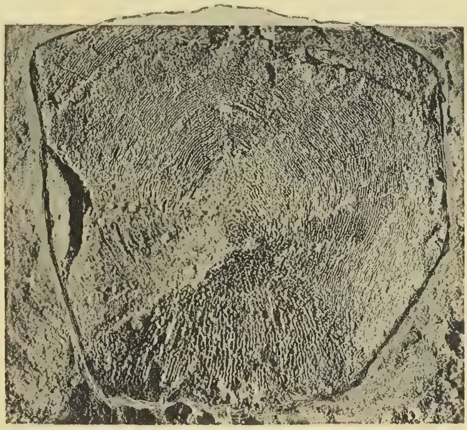

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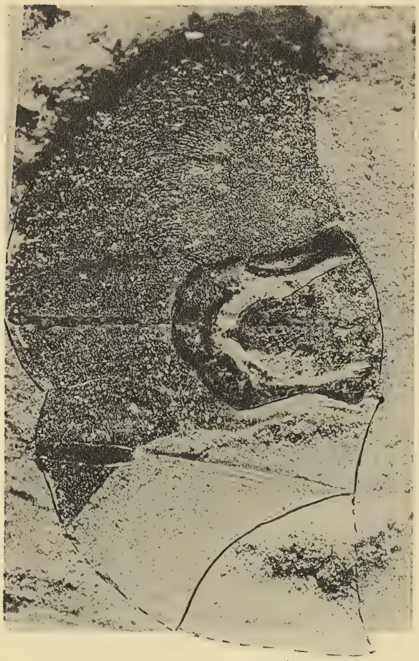
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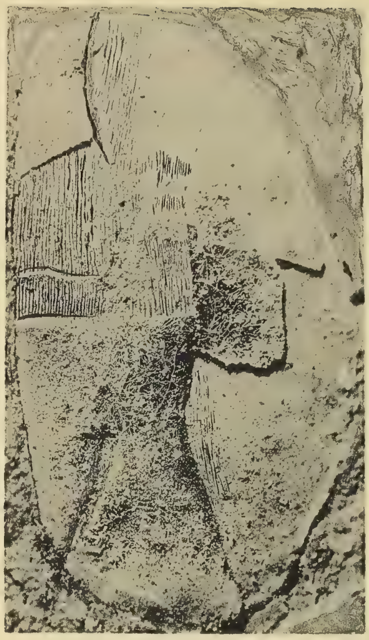
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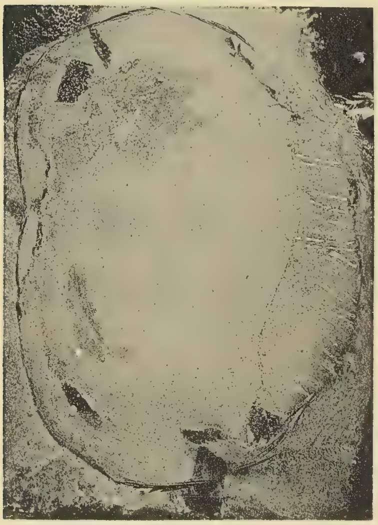
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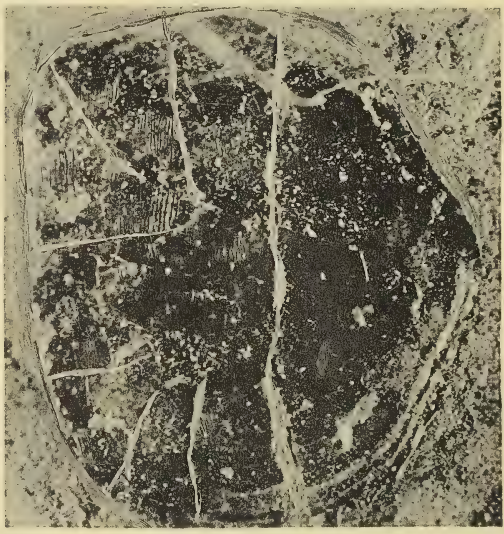
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PLATE 3

FIG. 1. *Helmintholepis* sp. Scale 16.5 mm. long by 21 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 6605 to 6608 feet. Moreno formation.

FIG. 2. *Kleinpellia morenoensis,* n. g. and n. sp. Lateral-line shield tentatively referred to this species, 5 mm. long by 8.4 mm. deep. Pure Oil Co. well, Chowchilla No. 1, at depth from 4737 to 4770 feet. Panoche formation. External side of shield.

FIG. 3. *Driverius cretaceus,* n. g. and n. sp. Type, no. 10305. Scale 3 mm. long by 4 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7137 to 7144 feet. Panoche formation. Smooth side of scale; mold of coarse side visible in places where scale is fragmentary.

FIG. 4. *Driverius cretaceus,* n. g. and n. sp. Cotype, no. 10306. Scale 4.1 mm. long by 7 mm. deep. Jergins Oil Co. well, Chaney Ranch No. 1, at depth from 7003 to 7009 feet. Panoche formation. Mold of coarse side of scale; smooth side preserved in left half of basal region and in small part of apical region.

Calif. Inst. Tech. Vert. Pale. Coll.

VI

A Miocene Mammalian Fauna from Beatty Buttes, Oregon

ROBERT E. WALLACE

With six plates and one text figure

[ISSUED JANUARY 25, 1946]

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A Miocene Mammalian Fauna from Beatty Buttes, Oregon

Introduction

Fossil mammalian remains were first discovered in tuff beds of the Beatty Buttes area in 1938 by Dr. Warren D. Smith and Lloyd Ruff, of the University of Oregon. Shortly thereafter, the occurrence was brought to the attention of Dr. Chester Stock by Dr. Smith. During the summer field seasons of 1940 and 1941 collecting parties from the California Institute of Technology examined the region and obtained much additional material.

The original locality at Beatty Buttes lies approximately 22 miles southwest of Blitzen, Oregon, and nearly 100 miles south of Burns, Oregon (see map, fig. 1). Here the tuff beds in which the fossil mammals are found border the north side of the volcanic cone of Beatty Buttes. Most of the material was collected in an area lying approximately 5 miles from the highest point of the cone and nearly due north of it. At a second locality, here designated Corral Buttes, occur fossiliferous deposits that are unquestionably like those exposed at Beatty Buttes. Fossils were discovered in these beds by K. A. Richey and J. C. Stock in 1941. Corral Buttes lies approximately 20 miles northwest of Beatty Buttes.

The author is indebted to Dr. Chester Stock not only for suggesting the problem, but also for valuable advice and criticism during the progress of the study. The field party of 1940 was under the supervision of Robert Leard, and that of the following year was led by K. A. Richey. The assistance and advice kindly given by E. L. Furlong and K. A. Richey are deeply appreciated. Dr. Robert W. Wilson furnished information which aided in the identification of some of the fossil rodents. Dr. W. D. Smith, who is familiar with the geology of the region, made many helpful suggestions. The illustrations were brought to finished form by David P. Willoughby.

Previous Work in Region

Geological investigation in southeastern Oregon has been for the most part of a reconnaissance type. Only a few areas have been mapped in detail geologically. In many instances even base maps are difficult to obtain.

Following an account in 1927 of the geology of Steens Mountain by W. D. Smith, Fuller in 1931 published the results of a study of the sequence of volcanic rocks in this region and included information regarding the geologic relations in the surrounding area. A paper by Piper, Robinson, and Park (1939) is concerned with the water resources of Harney Basin and sets forth the geology of the region about Malheur Lake, north of Beatty Buttes. In a much earlier paper, Waring (1908) considered the geology and water resources of an area

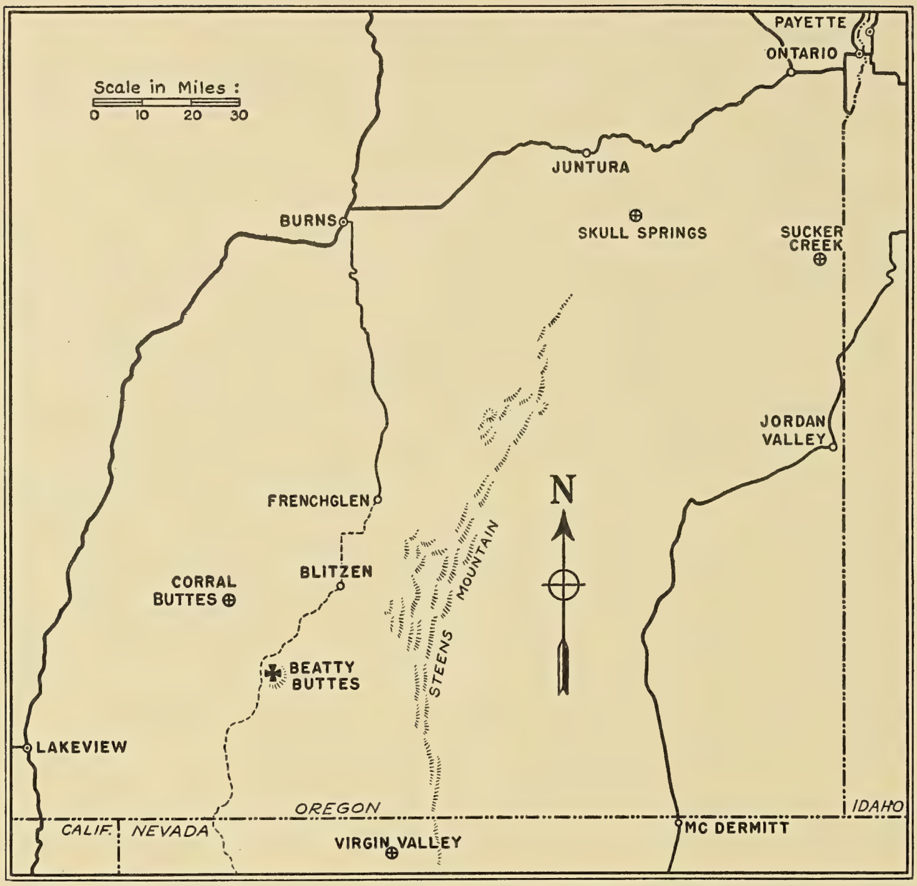


FIG. 1. Map showing the location of Beatty Buttes and Corral Buttes in relation to known fossil vertebrate localities in southeastern Oregon and in Nevada.

adjacent to Lake Abert and west of Beatty Buttes. Russell (1928) reported on the geology of the Warner Range in northeastern California.

Vertebrate remains of Miocene age were recorded from Sucker Creek, Oregon, by Scharf (1935); from Skull Springs, Oregon, by Gazin (1932); from the Mascall formation, Oregon, by Merriam (1907), and from Virgin Valley, Nevada, by Merriam (1911); from the Payette formation, Idaho, by Buwalda (1924); and from the Upper Cedarville formation, California, by Russell (1928).

Fossil floras are known from the Alvord Creek formation (Fuller, 1931), Upper Cedarville formation (Russell, 1928), Payette formation (Chaney, 1922), and Mascall formation (Chaney, 1925).

Geographical and Geological Relations

Beatty Buttes is a volcanic cone rising to a height of 7916 feet above sea level. It stands several thousand feet above a broad alluvial plain which is bordered on the east by the high Steens Mountain and on the west by the Hart Mountains. The climate of the area is arid and most of the vegetation is of a grassland and brush type. One of the largest of the few remaining herds of pronghorn antelope roams these plains. Other characteristic members of the animal community are the coyote, jack rabbit, and rattlesnake.

The fossil specimens were found in a series of acidic tuffs which form small buttes of the order of 100 to 150 feet in height surrounding the base of the main volcanic cone. Alluvial terraces composed of obsidian cobbles commonly cap these buttes, though near the volcanic cone itself basic flows cap the tuff beds. These flows apparently were extruded from the cone. The glass and pumice fragments of which the tuff is predominantly composed has an index of refraction ranging between 1.48 and 1.50. This would indicate a silica content of approximately 70 per cent (George, 1924).

The tuff beds show only slight deformation. Southerly dips of 5 to 8 degrees were the greatest divergence from the horizontal observed by the author. Elevation of the strata since the obsidian terraces were deposited has resulted in dissection of the tuff beds, forming the badlands in which the fossil material is exposed.

On the basis of a flora obtained from the Alvord Creek beds in Steens Mountain, Chaney (Fuller, 1931) believed that a correlation between these deposits and the Mascall formation was possible. This would likewise suggest a correlation with the Beatty Buttes horizon, since the fauna from the latter is nearly related to the Mascall assemblage. The Alvord Creek beds, however, lie below the Steens Mountain basalt, whereas the Beatty Buttes tuffs appear to rest on these basalts. This relation may be explained on the assumption that the resemblance between the floras of Alvord Creek and Mascall reflects in the main similar ecologic conditions without necessarily indicating an exact time equivalence. On the other hand, the extrusion of the basalt series may not have required a long time. Perhaps the fossiliferous deposits at Beatty Buttes are to be correlated with a higher part of the Mascall formation rather than with the plant-bearing Alvord Creek beds.[1] Russell (1928) described the Upper Cedarville formation from Warner Valley to the west of Beatty Buttes and stated that a fossil flora from it was regarded by Chaney as comparable in age to that of the Mascall. Thus the Upper Cedarville formation may be closely related in time to the Beatty Buttes horizon. Fossil vertebrates are known from the Upper Cedarville formation near Alturas, California, but no list of mammals has been published.

The stratification of the tuff beds does not suggest extensive fluviatile deposition, but rather an accumulation of the sediments in relatively quiet water or subaerially, or possibly under both conditions. The fossil remains suggest exposure to the weather before burial, not only by their fragmentary state of preservation, but also by the fact that a number of bones show the gnaw marks of rodents. Many of the fragments have their edges completely rounded by this type of attrition. Although evidence of rodent gnawing is often seen in fossil materials, the frequency of occurrence of this type of marking at Beatty Buttes suggests some specific cause. Absence of mineral salts in a region where accumulation of volcanic glass was widespread may have forced creatures to seek such materials in the scattered organic remains that were lying on the ground before they were buried. Moreover, the rather common occurrence of gnaw marks gives the impression that many rodents were present. Indeed, certain structures observed in the tuff beds may be the remains of rodent burrows that were subsequently filled with volcanic ash.

---

[1] Since the above was written, Axelrod (in Chaney, Condit, and Axelrod, Pliocene Floras of California and Oregon, Carnegie Inst. Wash. Pub. 553, 1944) concludes that the flora from the Alvord Creek formation is Lower Pliocene. The deposits would, therefore, be distinctly younger than those at Beatty Buttes, and this difference in age would imply a somewhat different interpretation of the geologic history of the region between the two localities.

LITHOLOGY

The following is a measured section of the rocks exposed at Beatty Buttes:

	Thickness (feet)
1. Basalt flows (estimated thickness)	35+
2. Stratigraphic distance between bottom of basalt and top of uppermost tuff bed exposed (estimated thickness)	25–30
3. Brown to gray-brown, tuffaceous silt. Top of the section not exposed	50
4. Brown, tuffaceous silt. Forms badland cliffs	10
5. Tuffaceous silt grading from gray at bottom to cream or buff at top. Many fossils occur in this unit. Usually exposed in badland slopes between cliff-forming units	32
6. Light-tan to brown tuffaceous silt containing many pumiceous fragments. Many fossils are preserved in this unit, especially toward the base. Forms badland cliffs	10
7. Brown to buff, tuffaceous silt	40
8. Coarse, greenish lapilli, or scoriaceous tuff. Base of section not exposed	70
Total	272–277+

COMPARATIVE LISTS OF MIOCENE FAUNAS FROM SOUTHEASTERN OREGON

BEATTY BUTTES	SUCKER CREEK	SKULL SPRINGS
	Insectivora	
Insectivore, possibly erinaceid		
	Carnivora	
Amphicyon frendens Matthew		Amphicyon cf. frendens Matthew
		Amphicyon sinapius Matthew or cf. Pliocyon medius Matthew
		Tomarctus cf. brevirostris Cope
		Euoplocyon (?) sp.
Canid (?) sp.	Canid (?) sp.	Canid (?) sp.
		Hemicyon, n. sp.
		Martes (Tomictis) gazini Hall

Beatty Buttes	Sucker Creek	Skull Springs
	Rodentia	
Sciurus sp.	Sciurus (?) sp.	Sciurus malheurensis Gazin
		Sciurus tephrus Gazin
		Citellus ridgwayi Gazin
Liodontia cf. alexandrae (Furlong)		Liodontia alexandrae (Furlong)
Mylagaulus cf. laevis Matthew	Mylagaulus cf. laevis Matthew	Mylagaulus cf. laevis Matthew
Diprionomys (?) sp.		Diprionomys (?) oregonensis Gazin
	Chalicomyid sp.	
	Lagomorpha	
Oreolagus (?), n. sp.		
	Proboscidea	
	Mastodont sp.	Mastodont sp.
	Perissodactyla	
Archaeohippus cf. ultimus (Cope)		
Hypohippus near osborni Gidley	Hypohippus near osborni Gidley	Hypohippus sp.
Parahippus cf. avus (Marsh)	Parahippus avus (Marsh)	Parahippus near coloradensis Gidley
Merychippus isonesus (Cope)	Merychippus isonesus (Cope)	Merychippus isonesus (Cope)
Merychippus cf. campestris Gidley	Merychippus brevidontus Bode	
Merychippus sp.		
Aphelops sp.	Rhinocerotid sp.	Rhinocerotid sp.
	Moropus sp.	Chalicothere (?) sp.
		Tapirid sp.
	Artiodactyla	
Oreodontid (?) sp.		
	Prosthennops (?) sp.	Platygonus (?) sp.
	Ticholeptus sp.	Ticholeptus (?) sp.
Dromomeryx borealis (Cope)	Dromomeryx near borealis (Cope)	Dromomeryx near borealis (Cope)
Merycodus, possibly n. sp.	Merycodus cf. nevadensis Merriam	Merycodus ? sp. *a*
Merycodus sp. (?)		Merycodus ? sp. *b*
Camelid (?) sp.	Camelid (?) sp. *a*	
	Camelid (?) sp. *b*	

Age of Fauna

The fossil vertebrate assemblage found at Beatty Buttes has much in common with those collected in the Miocene deposits of Sucker Creek and Skull Springs, Oregon. The similarity is so close that the three faunas appear to represent nearly identical horizons. The genus *Archaeohippus* and an insectivore are the only important members of the fauna from Beatty Buttes that do not occur in the assemblages from Sucker Creek and Skull Springs. The fauna from Beatty

Buttes is likewise comparable to that from the Mascall formation, Oregon, and that from the Virgin Valley formation, Nevada. *Merychippus isonesus, Dromomeryx borealis,* and *Mylagaulus* are conspicuously present in all these five faunas. However, the assemblages from Beatty Buttes, Sucker Creek, and Skull Springs show greater resemblance to that from Virgin Valley than they do to the Mascall fauna.

Several fossil mammals found at Beatty Buttes are known from the Sheep Creek beds of western Nebraska, and still others are present in the Lower Snake Creek beds, which overlie the Sheep Creek horizon. For example, *Archaeohippus* and *Amphicyon frendens* are described from the Sheep Creek horizon, and *Mylagaulus laevis* and *Hypohippus osborni* are present in the Lower Snake Creek fauna. The presence of these forms suggests at least a broad time relationship between the Oregon fauna and the two assemblages from the Great Plains. On the other hand, of the merychippine forms, only *M. primus* is recorded by Matthew (1924) from the Sheep Creek beds, whereas at Beatty Buttes occur several more advanced merychippines, suggesting an age slightly younger than that of the Sheep Creek fauna.

A slight resemblance appears to exist between the Oregon fauna and that from the Pawnee Creek of Colorado. In the latter occur *Merychippus campestris, Hypohippus osborni,* and *Aphelops megalodus.* These mammals are tentatively recorded from Beatty Buttes. The typical Pawnee Creek fauna is regarded by Osborn (1918) as slightly more progressive than the Mascall. Simpson (1933) considers the Pawnee Creek assemblage late Miocene in age.

Dougherty (1940) suggested an age for the Caliente fauna of California intermediate between the Mascall and the Sheep Creek, and further correlated the Caliente with the upper Temblor in the marine section of the California Coast Ranges. *Merychippus isonesus* is certainly more advanced than *M. carrizoensis* and indicates a slightly younger age for the fauna from Oregon.

Bode (1934) considered the Merychippus zone of the North Coalinga district to be intermediate between the Mascall and the Barstow. It was likewise correlated by Bode with the *Valvulineria californica* zone or basal Monterey of the California marine section.

Inasmuch as some of the fossil mammals from Beatty Buttes are like those from the Merychippus zone, a correlation of the former horizon with the marine Tertiary section of the California Coast Ranges is suggested. Thus, the assemblage from Beatty Buttes appears to represent a stage comparable in position to at least a lower part of the *Valvulineria californica* zone of the Middle Miocene as defined by micropaleontologists in the California marine section.

A discrepancy in these time relations becomes apparent, however, in that the fauna from Beatty Buttes is nearly identical in age with the Sucker Creek and Skull Springs faunas. These approximate in age the Mascall and Virgin Valley faunas, and would therefore represent a stage in the upper part of the Miocene, or Barstovian age, as defined by the committee of the Vertebrate Section of the Paleontological Society of America (Wood et al., 1941).

ENVIRONMENT OF FAUNA

The assemblage of fossil vertebrates represented at Beatty Buttes is not of sufficient size and variety to warrant definite statements as to the environmental conditions which prevailed during its period of existence and accumulation. Nevertheless, several suggestions seem worthy of mention.

The prevalence in a fossil fauna of grazing horses like *Merychippus* has often been regarded as evidence suggesting the presence of grassland country. Caution is necessary in the use of a criterion of this kind in determining what the particular kinds of environmental conditions were like during the past, for, as Bode (1934) points out, horses with hypsodont dentitions live today in open woodland country in certain parts of the world. Supporting the view that grasslands were in existence in the region of Beatty Buttes is the presence of *Merycodus,* a grazing type of antelope. On the other hand, the mylagaulid rodents and the genus *Liodontia* are often regarded as indicative of wooded areas, and so are the brachyodont, browsing types of ungulates, such as *Hypohippus* and *Dromomeryx.* Living rhinoceroses are found in regions which apparently include both grassland and open woodland, and the extinct *Aphelops* may have occupied a similar environment. A combination of faunal elements such as that comprising the assemblage from Beatty Buttes suggests, therefore, variable ecologic conditions in which open woodlands may have existed adjacent to plains.

The Payette formation of Idaho is tentatively correlated with the Sucker Creek horizon, and the latter in turn with Beatty Buttes. Although a Payette flora has been described (Chaney, 1922) from localities approximately 200 miles to the east of Beatty Buttes, what is known of the geological history of the intervening areas does not invalidate the view that essentially similar climatic conditions prevailed in southeastern Oregon and southwestern Idaho in mid-Tertiary time. Chaney concludes from a study of the Payette flora that the humidity was lower than that indicated by the Mascall flora. A similar climate may have prevailed during the period of deposition at Beatty Buttes. The relatively fine-grained character of the tuffs in which the fossil vertebrates are found suggests no great relief in adjacent areas. Similar topographic conditions are suggested by the Payette flora.

DESCRIPTION OF FOSSIL MATERIAL

Insectivore, possibly erinaceid

(Plate 3, figure 9)

A part of a right mandible with M_1–M_3, no. 3068, may represent an erinaceid in the fauna from Beatty Buttes. Unfortunately, the specimen was lost before a complete description was made. One photograph of a lateral view and the following notes are available as a record of this jaw fragment.

The cusps in the teeth in the Oregon specimen appear to be less prominent than in *Domnina gradata* Cope, described by Patterson and McGrew (1937). They are not so high in proportion to the anteroposterior and transverse diameters of the teeth as in *D. gradata.* M_3 is less reduced than in the latter form. These two features, low cusps and lack of reduction of M_3, suggest that the specimen from Beatty Buttes represents a more generalized type, and possesses to less extent the distinctive characters of soricids. This is significant since *D. gradata* is found in the Oligocene, whereas the Beatty Buttes form belongs to the later Miocene. No. 3068 certainly does not show the pronounced features seen in *Limnoecus tricuspis* Stirton from the Barstow Miocene of California.

In the following table the measurements of the Beatty Buttes specimen are compared with those of the holotype of *Domnina gradata* as given by Patterson and McGrew.

Comparative measurements (in millimeters)

	No. 3068 C.I.T.	*D. gradata,* no. 5353 F.M.N.H.
Anteroposterior diameter:		
M_1	*a*2.0	2.2
M_2	*a*2.0	2.1
M_3	*a*1.6	1.6
Depth of ramus under M_1	*a*2.0	2.4

a, approximate.

Amphicyon frendens Matthew

(Plate 4)

A fragment of a right ramus with P_4, M_1, M_2, and the alveoli for P_3 and M_3, no. 3192, Calif. Inst. Tech. Vert. Pale. Coll., is referred to *Amphicyon frendens* Matthew.

M_1 in this specimen is larger than that of the cotype of *Amphicyon sinapius,* no. 9357, Amer. Mus. Nat. Hist., from the Middle Miocene Pawnee Creek beds of Colorado. The teeth of no. 3192 are also considerably larger than comparable teeth of *A.* ref. to *sinapius,* no. 18258 A.M.N.H. (Matthew, 1924). A distinct difference between the Beatty Buttes specimen and no. 18258 is seen in the relation of depth of mandible to height of crown (protoconid) of M_1. In no. 3192 this depth immediately below M_1 is approximately three times the height of the crown of the tooth.

In size of teeth and in depth of mandible, no. 3192 is more like the type of *Amphicyon frendens,* no. 18913 A.M.N.H. The teeth in the Oregon specimen are actually slightly smaller than in no. 18913, and the hypoconid of M_1 is considerably smaller in proportion to the protoconid in the former than in the latter. The protoconid-paraconid blade tapers forward more than in the American Museum specimen, and is directed slightly more toward the inner side. M_1 in no. 3192 approximates in transverse diameter the comparable tooth in no. 376 C.I.T. of *A.* cf. *frendens,* from Skull Springs, but has a higher shearing blade. M_2 resembles in size and proportions the comparable tooth in no. 18913, but the notch between protoconid and hypoconid is more shallow. The mandible in no. 3192 is slightly longer than in the type specimen of *A. frendens,* although shorter than in *A.* ref. to *sinapius,* no. 18258 A.M.N.H. The convexity of the lower margin below the posterior end of M_2 is much more pronounced in the type than in the specimen from Beatty Buttes.

Comparative measurements (in millimeters)

	No. 3192 C.I.T. Beatty Buttes, Oregon	No. 376 C.I.T. Skull Springs, Oregon	*A. frendens*, type, no. 18913 A.M.N.H.	*A.* ref. to *sinapius*, no. 18258 A.M.N.H.	*A. sinapius*, cotype, no. 9357 A.M.N.H.
M_1, length from base of metaconid to anterior end of tooth	26.0	25.5	25.7	23.4	23.5
M_1, anteroposterior diameter	37.0	....	....	*a*34.0	....
M_1, transverse diameter at posterior base of metaconid	17.0	17.5	20.4	*a*17.4	15.0
M_1, transverse diameter across notch between paraconid and protoconid	15.5	17.0	15.7	14.6	14.3
M_1, height of protoconid	24.0	22.0	27.0	*a*21.0	....
M_2, anteroposterior diameter	27.0	....	30.0	*a*28.0	....
M_2, transverse diameter at notch between hypoconid and protoconid	17.5	....	19.6	.....	....
Length, anterior end of P_4 to posterior end of M_2	85.5	....	....	.....	....
Depth of mandible below protoconid of M_1	50.0	*a*45.0	....	*a*83.0	....

a, approximate.

Canid (?) sp.

A fragmentary jaw, no. 3067 Calif. Inst. Tech. Vert. Pale. Coll., with only a part of P_4 remaining of the dentition, is referred tentatively to the Canidae. The specimen approaches in size the jaw of the present-day *Vulpes macrotis.*

Comparative measurements (in millimeters)

	Canid (?) sp., no. 3067 C.I.T.	*Vulpes macrotis* Merriam
Length, anterior end of alveolus for P_3 to posterior end of alveolus for M_3	34.0	34.8
P_4, anteroposterior diameter	8.0	7.8
Depth of jaw below M_1	10.8	9.9

Sciurus sp.

(Plate 3, figures 5, 6)

Several isolated upper teeth, nos. 3077A and 3077B, and two fragments of maxillaries with teeth, nos. 3076 and 3078, Calif. Inst. Tech. Vert. Pale. Coll., unquestionably represent the genus *Sciurus,* but incomplete preservation of the material prevents specific identification.

The characters of the upper cheek teeth are well displayed in nos. 3077A and 3077B, for the crowns of these specimens are practically unworn. The teeth are quadrate in shape and have four transverse lophs. The two outer lophs are less prominently developed than the two inner ones. The inner lophs terminate externally in pronounced cusps. In size the teeth are comparable to those in *S. malheurensis,* no. 129 C.I.T., described by Gazin (1932) from Skull Springs, Oregon. The material from Beatty Buttes may represent that species. The teeth of *Sciurus griseus,* a modern tree squirrel, are slightly larger than those of the Oregon fossil.

Comparative measurements (in millimeters)

	Sciurus sp., no. 3077A C.I.T.	*S. malheurensis,* no. 129 C.I.T.	*S. griseus,* no. 9601 C.I.T.
M^1, anteroposterior diameter	2.2	2.4	2.9
M^1, transverse diameter	2.7	2.7	3.3

Liodontia cf. **alexandrae** (Furlong)

(Plate 3, figures 7, 8)

A maxillary fragment, no. 3083, Calif. Inst. Tech. Vert. Pale. Coll., including P^3, P^4, M^1, and a part of M^2, seems referable to *Liodontia alexandrae.* Two lower premolars, nos. 3082A and 3082B, and several upper molars, nos. 3084A and 3084B, are also present. An anterior part of a skull with two incisors, no. 3087, is tentatively referred to this species.

Miller and Gidley (1918) established the genus *Liodontia* on the basis of the characters displayed by *Aplodontia alexandrae* Furlong from the Thousand Creek and Virgin Valley formations of Nevada. Gazin (1932) recognized specific differences between the type specimen from the Virgin Valley Miocene and the cotype from the Thousand Creek Pliocene, and proposed for the latter the name *Liodontia furlongi.*

P^4 in no. 3083 from Beatty Buttes is comparable in size and in acuteness of mesostyle to the corresponding tooth in the type specimen of *Liodontia alexandrae,* no. 11325, Univ. Calif. Vert. Pale. Coll., from Virgin Valley. A noticeable difference, however, is the presence of seven enamel lakes on the occlusal surface of no. 3083, whereas not more than four lakes are noted in individuals of *Liodontia alexandrae* described from other Miocene localities. The teeth in no. 3083 are only slightly worn, however, and this may account for the difference in number of lakes. The three additional lakes are arranged along a line which passes approximately through the mesostyle, dividing the tooth in half transversely.

The two lower fourth premolars, nos. 3082A and 3082B, have conspicuous anteroexternal folds, a feature which is considered characteristic of *Liodontia alexandrae,* when seen in teeth of moderate wear.

Mylagaulus cf. **laevis** Matthew

(Plate 3, figures 1–1*d*, 2–2*d*)

Mylagaulus is represented in the collections from Beatty Buttes by approximately 25 isolated teeth. The majority of these specimens are enlarged fourth premolars. The teeth from the Oregon locality are comparable in size to those of *M. sesquipedalis* and *M. laevis.* The form from Beatty Buttes, however, shows distinct external flattening of the upper premolars, a feature typical of *M. laevis,* whereas in *M. sesquipedalis* the teeth are described as having a "regularly oval" occlusal surface. The teeth from Beatty Buttes are also similar to those from Skull Springs which have been referred to *M. laevis* (Gazin, 1932).

Features common to the specimens of P^4 from Beatty Buttes and Skull Springs include the anteroexternal and anterointernal grooves, concave curvature of external face along vertical axis, and presence of five to eight enamel lakes depending on stage of wear of crown. The lakes are elongated and are oriented roughly parallel to the anteroposterior axis of the tooth. In several specimens the teeth taper anteriorly.

The lower premolars from Beatty Buttes, no. 3070, Calif. Inst. Tech. Vert. Pale. Coll., are more extended anteroposteriorly than the upper premolars. Usually six lakes are present, and the number is apparently more persistent with further wear of the tooth than is the case with the number of lakes in the upper premolars. The lakes occur in two rows of three each, one row having a position along the external border and the other along the internal border. The rows are oriented parallel to the anteroposterior axis of the tooth, but the elongation of individual lakes is transverse to this axis and the trends are anteroexternal.

Several isolated second upper molars, nos. 3072 and 3073, are in the collection. Two upper molars of *Mylagaulus* have nearly equal transverse and anteroposterior diameters. In diameter these teeth approximate half the size of the upper fourth premolars. Five enamel lakes are present. The four large lakes are located at the corners of a square. The fifth or smaller lake lies halfway between the two outer lakes and closer to the outer wall. The individual lakes are extended in a direction parallel to the anteroposterior axis of the tooth. Two molars, tentatively regarded as of the lower dentition, have a circular outline of the occlusal surface, with lakes numbering four in one and five in the other.

Several fragments of teeth and skeletal elements from Corral Buttes represent *Mylagaulus*. So far as can be determined from the scant material available, this form is identical with that recorded from Beatty Buttes.

Measurements (in millimeters) of teeth of Mylagaulus cf. laevis

Specimen no.	Transverse diameter	Anteroposterior diameter
3069A, P^4	7.9	9.8
3069B, P^4	6.1	9.0
3069C, P^4	7.1	9.7
3069D, P^4	5.4	9.0
3070A, P_4	5.2	10.0
3070B, P_4	5.6	10.2
3070C, P_4	5.1	11.9
3070D, P_4	4.8	*a*10.4
3070E, P_4	5.0	9.4
3073A, M^2	4.4	4.6
3073B, M^2	4.0	3.8

a, approximate.

Diprionomys (?) sp.

A badly broken cheek tooth suggests a rodent similar to *Diprionomys* (?) *oregonensis*, described by Gazin from the Skull Springs Miocene.

Oreolagus (?) n. sp.

(Plate 3, figures 3, 4)

A left maxillary with P^3–M^2, no. 3074, Calif. Inst. Tech. Vert. Pale. Coll., and a right ramus with M_1–M_2, no. 3088, may represent the Ochotonidae. No. 3088 is similar to *Oreolagus nevadensis,* described and illustrated by Dice (1917) from the Virgin Valley Miocene, and to *Sylvilagus* ? sp., recorded by Hall (1930) from the Fish Lake Valley beds of Nevada, and may represent a similar form. No. 3088 is apparently an ochotonid rather than a leporid, for the anterior and posterior columns of the teeth are joined by narrow connections and are not closely fused. In the upper cheek teeth of no. 3074, however, the two columns are broadly united. The form from Beatty Buttes is considerably larger than either *Oreolagus nevadensis* or *Sylvilagus* ? sp., but is smaller than *Hypolagus vetus.*

Descriptions of ochotonid material from the North American Tertiary are rare. The specimens from Beatty Buttes probably belong to an undescribed species.

Measurements (in millimeters) of specimens of Oreolagus (?), n. sp.

Length of tooth row, P^3–M^2, no. 3074	6.4
Greatest transverse diameter of M^1, no. 3074	3.0
Length of tooth row, M_1–M_2, no. 3088	4.3
Greatest transverse diameter of M_1, no. 3088	1.9

Archaeohippus cf. **ultimus** (Cope)

(Plate 2, figures 4, 5)

A single upper tooth, no. 3061 Calif. Inst. Tech. Vert. Pale. Coll., lacks the outer wall. It is referred to the genus *Archaeohippus* and is compared with *A. ultimus* and *A. mourningi.* The specimen appears to fall within the size range of teeth of *A. ultimus* from the Mascall. It likewise resembles teeth of *A. mourningi* from the Barstow Miocene, as well as teeth referred to this species and described by Bode (1933) from the north Coalinga district, California.

In no. 3061 the protocone is not so distinctly separated from the protoconule as in the unworn tooth of the type of *A. mourningi,* probably because of greater wear in the former. In other respects the two teeth are almost identical. The hypostyle is well developed, and cement is lacking. Protocone and hypocone are enlarged and conical in shape, thereby constricting somewhat the lingual entrance to the valley between protoloph and metaloph. No crochet is present.

Fragments of two superior cheek teeth, nos. 3204 and 3203 C.I.T., were found in the deposits at Corral Buttes and represent *Archaeohippus.* No. 3204, apparently P^2, is slightly larger than the tooth from Beatty Buttes. No. 3203 represents, as nearly as can be determined, the same form as no. 3061.

Measurements (in millimeters) of upper cheek tooth of Archaeohippus cf. ultimus, no. 3061 C.I.T.

Anteroposterior diameter	13.5
Approximate transverse diameter	13.0
Approximate height	11.0

Hypohippus near **osborni** Gidley

(Plate 2, figures 1, 1*a*, 2, 2*a*)

An unworn P^3, no. 3199, Calif. Inst. Tech. Vert. Pale. Coll., and a slightly worn M_3, no. 3063 C.I.T., represent the genus *Hypohippus* in the collection. No. 3199 is similar to P_3 in the type specimen of *Hypohippus osborni* from the Middle Miocene, Pawnee Creek formation. The only noteworthy differences are the presence in no.

3199 of a well developed cingulum at the base of the protocone, and a slightly smaller anteroposterior diameter. No. 3063 is comparable in size and in character of crown to a specimen from Virgin Valley, described by Merriam as near *H. osborni*. In no. 3063 the hypoconid ridge is distinct from the metastylid, and an external cingulum is only slightly developed. Specimens from Skull Springs and Virgin Valley identified as *Hypohippus* are likewise similar to the tooth from Beatty Buttes.

A fragment of a ramus, no. 3198 C.I.T., with part of a lower premolar, collected at Corral Buttes, represents apparently the same form as that found at Beatty Buttes. The external cingulum in no. 3198 appears to be slightly heavier than in the latter.

Measurements (in millimeters) of teeth of Hypohippus near osborni

	P^3 no. 3199 C.I.T.	M_3 no. 3063 C.I.T.
Greatest anteroposterior diameter	20.0	24.4
Greatest transverse diameter	27.5	15.6
Height of paracone	16.7	...
Height of metaconid	...	11.0

Parahippus cf. **avus** (Marsh)

(Plate 2, figures 3, 3*a*)

Referred to *Parahippus* is a fragmentary and unworn M_1 or P_4, no. 3064, Calif. Inst. Tech. Vert. Pale. Coll. This specimen is similar to P_4, no. 442 C.I.T., from the Sucker Creek Miocene, which was identified as *Parahippus avus* by Scharf (1935). It resembles also no. 19403, Univ. Calif. Vert. Pale. Coll., from Virgin Valley, identified as *P. avus* by Merriam. In no. 3064 the metaconid-metastylid pillar is prominent and higher than the protoconid or hypoconid. An external cingulum is present. Cement is entirely lacking. The comparatively large size and subhypsodont character of the tooth suggest a slightly more advanced parahippine stage than that of *P. avus*.

Measurements (in millimeters) of M_1 *? of Parahippus cf. avus*

Greatest transverse diameter	16.9
Height of metaconid	14.4

Merychippus isonesus (Cope)

(Plate 2, figures 6, 6*a*, 7, 7*a*, 8, 8*a*)

Most of the equine material from Beatty Buttes is referred to this species. It is represented by a fragment of ramus, no. 3057, Calif. Inst. Tech. Vert. Pale. Coll., with M_1–M_3 inclusive, approximately 14 separate and fairly well preserved teeth, and many tarsal and carpal elements.

The upper teeth have medium high crowns. The radius of curvature of the external side approximates 1 to 2 inches. Cementation is variable, but is fairly heavy in several specimens. The anteroposterior and transverse diameters of the crown are often nearly equal. The fossettes are open internally in some instances, especially in early stages of wear. The protocone and hypocone are of subequal or equal size, with the hypocone usually slightly smaller and more flattened than the protocone. In all specimens the protocone is distinct from the protoloph, but the pli protoconule is usually present. The hypocone in all but one specimen is joined to the metaloph, although in P^2 this union is established by only a narrow isthmus.

Specimen no. 3052 is similar to P^2 in the type of *M. isonesus,* no. 8175, Amer. Mus. Nat. Hist. The fossettes are open and have practically no plications. Hypocone and protocone are entirely separate from protoloph and metaloph in at least the upper part of the tooth.

Specimens 3049 and 3050 from Beatty Buttes are similar to M^1 of the type, no. 8175 A.M.N.H. In no. 3049 the crochet does not quite reach the protoloph and the prefossette remains open toward the inner side by a narrow channel. The plications on the border of the postfossette are not so complex as in the type specimen. A plication or style is present on the external enamel wall in the region of the hypostyle. This feature is likewise prominent in no. 3047. The only appreciable difference between no. 3050 and the type of *M. isonesus* is the presence in the former of a slightly smaller number of plications on the anterior border of the postfossette.

A superior milk tooth, no. 3096 C.I.T., is brachyodont and lacks cement. This specimen resembles a comparable tooth, no. 440 C.I.T., described by Scharf (1935, p. 108), and a Dp^4 and P^3, no. 1500 C.I.T., described and figured by Bode (1934, p. 63). In no. 3096 the protocone and hypocone each have a conical shape, a character which Bode points out is distinctive of *Merychippus isonesus.*

The deposit of cement in the permanent teeth is apparently considerably less in specimens from Beatty Buttes than in those from Skull Springs, Sucker Creek, or Virgin Valley. Teeth in the present collection appear to be slightly larger than those from Sucker Creek, and approximate more nearly in size those referred to *M. isonesus* from Skull Springs and Virgin Valley.

Unfortunately, the lower dentition is represented only by the well worn teeth in the fragmentary ramus, and by three practically unworn specimens. Two of the latter are possibly milk teeth.

The species *Merychippus isonesus* is known from the deposits at Corral Buttes by several separate teeth, including a fragment of a milk tooth, and also by isolated carpal and tarsal elements. The teeth resemble those collected at Beatty Buttes in stage of development.

Measurements (in millimeters) of teeth of Merychippus isonesus

Specimen no.	Anteroposterior diameter	Greatest transverse diameter	Approximate height of crown
3047, P^4	21.8	20.5	30
3049, M^1	21.3	20.0	29
3050, M^1	20.7	20.5	21
3051, P^2	25.0	16.5	28
3052, P^2	23.0	16.0	23
3056, M_3	25.0	9.8	16
3057, M_1	17.0	....	10
3057, M_2	17.3	11.0	9
3057, M_3	24.0	12.0	10
3091, M^2	21.0	20.0	30.5
3092, M^2	20.8	17.0	27
3093, M^1	22.0	21.0	31
3094, M^1	22.0	....	34
3095, P^2	25.0	15.0	23
3096, Dp^4	20.0	19.0	15

Merychippus cf. **campestris** Gidley

(Plate 1, figures 1, 1*a*, 2, 2*a*, 3, 3*a*, 4, 4*a*)

A single P^4, no. 3084, Calif. Inst. Tech. Vert. Pale. Coll., and two lower cheek teeth, nos. 3055 and 3062 C.I.T., P_3 and M_1 respectively, differ from comparable teeth of *M. isonesus* but resemble those of *Merychippus campestris* and *M. sejunctus* from the Middle Miocene, Pawnee Creek beds. No. 3084 is larger than P^4 in the type of *M. sejunctus,* no. 8291, Amer. Mus. Nat. Hist., and is smaller than the comparable tooth in the type of *M. campestris,* no. 9096 A.M.N.H.

Comparative measurements (in millimeters)

Specimen no.	Anteroposterior diameter	Transverse diameter	Approximate height
3084, P^4	21.0	24.0	24
3055, P_3	20.8	13.0	22
3062, M_1	21.1	11.1	20

	No. 3207 C.I.T.	*M. campestris,* type, no. 9096 A.M.N.H.	*M. sejunctus,* type, no. 8291 A.M.N.H.
Anteroposterior diameter:			
P^1	14.0	....	....
P^2	25.3	27.8	23.9
P^3	22.6	23.3	19.0
P^4	20.2	23.3	18.9
M^1	19.8	20.8	17.0
M^2	20.2	22.0	18.0
M^3	20.1	21.4	20.6
Length, P^2–M^3	131.0	135.4	117.0
Anteroposterior diameter:			
P_2	25.0	26.3	24.2
P_3	20.0	21.1	17.0
P_4	19.1	19.0	16.8
M_1	20.8	23.0	18.5
M_2	21.8	22.8	18.5
M_3	22.5	22.8	18.8
Length, P_2–M_3	131.0	134.0	113.5

In no. 3084 the protocone and hypocone are joined and there is a small enamel lake at the inner end of the postprotoconal valley. The fossettes have simple borders, and a moderate deposit of cement is present. A pli caballin is present in the specimen from Beatty Buttes and in the type of *M. campestris,* but is absent from the type of *M. sejunctus.* In *M. campestris* and *M. sejunctus* the metastyle and parastyle are directed more anteriorly than in the specimen from Beatty Buttes. In the latter these styles project at nearly right angles to the anteroposterior axis of the tooth crown.

Two lower teeth are tentatively assigned to *M. campestris.* P_3, no. 3055, is similar to a comparable tooth, no. 8273 A.M.N.H., that has been referred to *M. sejunctus* (Cope). M_1, no. 3062, resembles M_1, no. 8273 A.M.N.H. The two teeth in the collection of the American Museum are more heavily cemented than any of the merychippine specimens in the collection from Beatty Buttes. Likewise the transverse diameter exceeds that in lower teeth of *Merychippus* from this locality.

Remains of a single individual of *Merychippus,* no. 3207 C.I.T., which include a fragmentary skull with complete set of worn teeth, a left ramus with cheek teeth, and scattered skeletal elements, were collected at the Corral Buttes locality. The upper cheek teeth in no. 3207 are similar in enamel pattern to the type of *M. sejunctus,* no. 8291 A.M.N.H., but the tooth row is somewhat longer. No. 3207 approaches *M. campestris,* no. 9096 A.M.N.H., in size. The lower cheek teeth in no. 3207 are similar to those of the type of *M. campestris.*

In the stage of wear seen in no. 3207, protocone and hypocone are joined to metaloph and protoloph. The plications on the fossette borders are also greatly simplified. A hypostyle is present in M^2 and M^3 of no. 3207, but is absent from the remaining teeth. These characters have probably been acquired through wear of the occlusal surface. A small accessory style, immediately anterior to the protocone, is present in M^1 of no. 3207.

Merychippus sp.

(Plate 1, figures 5, 5*a*)

An unworn M_3, no. 3054, Calif. Inst. Tech. Vert. Pale. Coll., has a considerably longer crown than do the merychippine teeth already described from Beatty Buttes. The specimen may belong to a distinct species. No. 3054 compares in height of crown with *M. paniensis,* no. 8255, Amer. Mus. Nat. Hist., from the Pawnee Creek.

An unworn M_3, no. 3202 C.I.T., from Corral Buttes undoubtedly represents the same species as no. 3054 from Beatty Buttes.

Measurements (in millimeters) of M_3 of Merychippus sp.

Specimen no.	Anteroposterior diameter	Transverse diameter	Approximate height
3054	24.0	9.1	31
3202	24.0	10.2	34

Aphelops sp.

(Plate 5, figures 1, 2, 2*a*)

Two slightly worn lower teeth, nos. 3085 and 3207, Calif. Inst. Tech. Vert. Pale. Coll., are referred to the genus *Aphelops.* In size and in degree of brachyodonty these specimens resemble *Aphelops megalodus* from the Snake Creek beds of Nebraska and the Pawnee Creek beds of Colorado.

According to Matthew, the three genera of rhinoceroses of the Middle Miocene, namely *Aphelops, Peraceras,* and *Teleoceras,* are not readily distinguished. The dentition of *Teleoceras* is slightly more hypsodont than that of *Aphelops,* and in this character the material from Beatty Buttes is more like the latter genus.

A single upper cheek tooth of *Aphelops,* no. 3206 C.I.T., and scattered skeletal fragments referred to this form were obtained at the Corral Buttes locality. The tooth is well worn, but appears to have been moderately short-crowned. The antecrochet is usually the only accessory crest in molars of *A. megalodus,* and in this specimen shows slight development. The posterior valley on the tooth crown is closed and thus suggests a form more advanced than *A. megalodus.* This feature, however, may be due to the advanced stage of wear.

Measurements (in millimeters) of teeth of Aphelops sp.

Specimen no.	Anteroposterior diameter	Transverse diameter	Greatest height
3206, P^4?	49	58	25
3207, M_1?	51	33	30
3085, M_1?	49	28	33

Oreodontid (?) sp.

No fossil remains of oreodons are certainly identified in the collection. An enamel fragment from Beatty Buttes may belong to this group of artiodactyls.

Dromomeryx borealis (Cope)

(Plate 6)

The only fairly well preserved skull of a fossil mammal from Beatty Buttes belongs to *Dromomeryx*. This specimen, no. 3060, Calif. Inst. Tech. Vert. Pale. Coll., includes enough of the cheek-tooth series to permit satisfactory comparisons. The skull is considerably crushed and distorted, and only the basal parts of the horns are preserved. A single M_3, no. 3065 C.I.T., is also present in the collection.

Measurements (in millimeters) of Dromomeryx borealis

Specimen no.	Anteroposterior diameter	Transverse diameter	Approximate height	Tooth wear
3060, M^3	23	24	11	Worn
3060, M^2	21	23	9	Worn
3060, M^1	18	*a*21	8	Worn
3060, P^4	14.5	17	7.5	Worn
3060, P^3	17	16	7	Much worn
3060, P^2	....	12.5	3	Much worn
3065, M_3	32.5	15	13.5	Only slightly worn

Dimensions (no. 3060)	Approximate measurement
Length of preserved part of skull	397
Width measured at outer surface of M^2	86
Length of upper cheek-tooth series	104
Length of upper premolar series	44
Length of upper molar series	60

a, approximate.

Skull. The description of the skull of *Dromomeryx borealis* as given by Douglass (1909) applies well to the present specimen. In brief, the skull of *Dromomeryx* from Beatty Buttes is characterized by a rather long, narrow facial part. The mid-point between the extreme anterior end and posterior end of the skull coincides approximately with the anterior border of the orbit and the posterior end of the molar series. Anterior to the orbits are prominent fossae or pits in the facial part of the maxillary. These are not present in no. 827, Carnegie Mus. Coll., nor in the type, no. 8132, Amer. Mus. Nat. Hist. These depressions on either side of the snout are apparently not due to crushing of the specimen.

Dentition. The molar teeth are well worn, but are similar in size and pattern to specimens no. 827 and no. 1542 Carnegie Mus., described by Douglass. In no. 3060 from Oregon the teeth lack the accessory style or pillar between the two principal inner cusps. Lacking also is the spur which in no. 1542 extends from the inner posterior crescent into the valley between the posterior internal and external crescents. However, both this spur and a similar one branching from the anterior internal crescent are absent from no. 827. In their slightly complex enamel pattern, the crescents of the premolars in the Oregon specimen are more like those in no. 1542 than those in no. 827.

The single third lower molar, no. 3065 C.I.T., agrees well in pattern with the specimen of *Dromomeryx borealis* figured by Douglass (1909), but it is approximately 10 per cent larger than the latter.

Merycodus, possibly n. sp.

(Plate 5, figures 3, 4)

A fragment of a right ramus, no. 3066, Calif. Inst. Tech. Vert. Pale. Coll., with P_4–M_2 poorly preserved, is larger than that in *Merycodus loxocerus,* but is not quite so large as that in *M. hookwayi.* It is larger than *M. nevadensis,* described by Merriam (1911) from the Virgin Valley beds, northwestern Nevada. In P_4 the anterior and posterior lobes that project inward are particularly well developed. The posterior lobe has an enclosed enamel lake. At the inner posterior side of the middle lobe, an extension of the enamel wall of this lobe projects backward. Because of this there is no open valley, but only a V-shaped incision between the middle and posterior lobes. The anterior valley between middle and anterior lobes is also not so broadly open toward the lingual face as in *M. loxocerus.*

The molar teeth are not so long-crowned as in *M. hookwayi.* In these teeth the outer crescents are rounded, not acutely ridged. An intercrescent columnette is present in M_2 of no. 3066. The depth of the ramus below the molars is slightly greater in no. 3066 than in either the type or the paratype of *M. loxocerus* from the Tonopah Miocene, but this feature is apparently variable in the Nevadan specimens. Comparison with merycodont material from Sucker Creek and from Skull Springs is difficult because of incomplete preservation of the latter. No noticeable differences are seen.

A horn-core fragment, no. 3194 C.I.T., approximates *M. loxocerus* in its diameter. This measurement is slightly larger than that in *Merycodus nevadensis* from Virgin Valley.

Two horn-core fragments, nos. 3196 and 3197 C.I.T., are also known from Corral Buttes.

Measurements (in millimeters) of Merycodus, possibly n. sp.

Length of preserved part of cheek-tooth series, measured at level of occlusal surface, no. 3060	24.6
Depth of jaw below M1, no. 3060	15.5
Diameter of horn core above burr, no. 3194	12.3

Merycodus sp. (?)

A fragment of an inferior molar, no. 3195, Calif. Inst. Tech. Vert. Pale. Coll., is considerably larger than *M. loxocerus,* both in height and in anteroposterior diameter. It approaches *M. hookwayi* more nearly in size.

Camelid (?) sp.

Fragments of a tooth suggest the presence of the camel family in the Beatty Buttes fauna, but no generic designation is possible on the basis of these scanty remains.

BIBLIOGRAPHY

BODE, F. D. 1933. Anchitheriine horses from the Merychippus zone of the North Coalinga district, California. Carnegie Inst. Wash. Pub. 440, V, pp. 43–58.

——— 1934. Tooth characters of protohippine horses with special reference to species from the Merychippus zone, California. Carnegie Inst. Wash. Pub. 453, V, pp. 39–63.

BUWALDA, J. P. 1924. The age of the Payette formation and the old erosion surface in Idaho. Science, n. s., vol. 60, pp. 572–573.

CHANEY, R. W. 1922. Notes on the flora of the Payette formation. Amer. Jour. Sci., ser. 5, vol. 4, pp. 214–222.

——— 1925. The Mascall flora—its distribution and climatic relation. Carnegie Inst. Wash. Pub. 349, II, pp. 23–48.

COPE, E. D. 1878. U. S. Geol. and Geog. Surv. Terrs., vol. 4, pp. 384–385.

DICE, L. R. 1917. Systematic position of several American Tertiary lagomorphs. Univ. Calif. Publ., Bull. Dept. Geol., vol. 10, no. 12, pp. 179–183.

DOUGHERTY, J. F. 1940. A new Miocene mammalian fauna from Caliente Mountain, California. Carnegie Inst. Wash. Pub. 514, VIII, pp. 109–143.

DOUGLASS, E. 1909. *Dromomeryx,* a new genus of American ruminants. Ann. Carnegie Mus., vol. 5, no. 4, pp. 457–479.

FULLER, R. E. 1931. The geomorphology and volcanic sequence of Steens Mountain in southeastern Oregon. Univ. Wash. Publ. Geol., vol. 3, no. 1, pp. 1–130.

FURLONG, E. L. 1910. An aplodont rodent from the Tertiary of Nevada. Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, no. 26, pp. 397–403.

——— 1927. The occurrence and phylogenetic status of *Merycodus* from the Mojave Desert Tertiary. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 17, no. 4, pp. 145–186.

——— 1934. New merycodonts from the Upper Miocene of Nevada. Carnegie Inst. Wash. Pub. 453, I, pp. 1–10.

GAZIN, C. L. 1932. A Miocene mammalian fauna from southeastern Oregon. Carnegie Inst. Wash. Pub. 418, III, pp. 37–86.

GEORGE, W. O. 1924. The relation of the physical properties of natural glasses to their chemical composition. Jour. Geol., vol. 32, pp. 353–372.

HALL, E. R. 1930. Rodents and lagomorphs from the later Tertiary of Fish Lake Valley, Nevada. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 19, no. 12, pp. 295–312.

MATTHEW, W. D. 1902. New Canidae from the Miocene of Colorado. Bull. Amer. Mus. Nat. Hist., vol. 16, art. 21, pp. 281–290.

——— 1902. A horned rodent from the Colorado Miocene. With a revision of the Mylagauli, beavers and hares of the American Tertiary. Bull. Amer. Mus. Nat. Hist., vol. 16, art. 22, pp. 291–310.

——— 1924. Third contribution to the Snake Creek fauna. Bull. Amer. Mus. Nat. Hist., vol. 50, art. 2, pp. 59–210.

——— 1932. A review of the rhinoceroses with a description of *Aphelops* material from the Pliocene of Texas. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 20, no. 12, pp. 411–482.

MERRIAM, J. C. 1907. Carnivora from the Tertiary formations of the John Day region. Univ. Calif. Publ., Bull. Dept. Geol., vol. 5, no. 1, pp. 1–64.

——— 1911. Tertiary mammal beds of Virgin Valley and Thousand Creek in northwestern Nevada. Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, no. 11, pp. 199–304.

Miller, G. S., and J. W. Gidley. 1918. Synopsis of the supergeneric groups of Rodents. Jour. Wash. Acad. Sci., vol. 8, p. 440.

Osborn, H. F. 1918. Equidae of the Oligocene, Miocene and Pliocene of North America. Iconographic type revision. Mem. Amer. Mus. Nat. Hist., n. s., vol. 2, pt. 1. 330 pp.

Patterson, B., and P. O. McGrew. 1937. A soricid and two erinaceids from the White River Oligocene. Geol. Ser. Field Mus. Nat. Hist., vol. 6, no. 18, pp. 245–271.

Piper, S. M., T. W. Robinson, and C. F. Park, Jr. 1939. Geology and groundwater resources of the Harney Basin, Oregon. U. S. Geol. Surv. Water-Supply Paper 841. 189 pp.

Russell, R. J. 1928. Basin range structure and stratigraphy of the Warner Range, northeastern California. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 17, no. 11, pp. 387–496.

Scharf, D. W. 1935. A Miocene mammalian fauna from Sucker Creek, southeastern Oregon. Carnegie Inst. Wash. Pub. 453, VII, pp. 98–118.

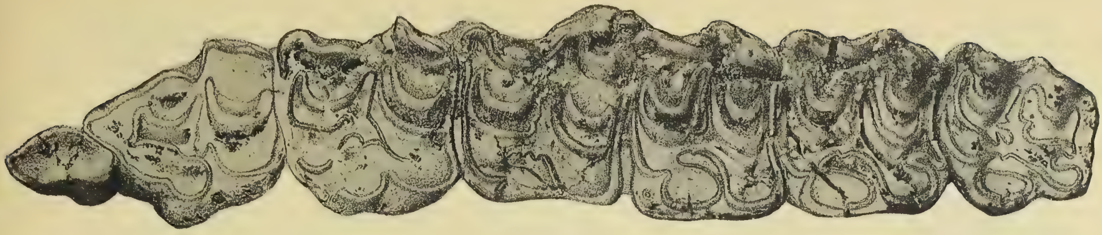
Simpson, G. G. 1933. Glossary and correlation charts of North American Tertiary mammal-bearing formations. Bull. Amer. Mus. Nat. Hist., vol. 67, art. 3, pp. 79–121.

Smith, W. D. 1927. Contribution to the geology of southeastern Oregon (Steens and Pueblo Mountains). Jour. Geol., vol. 35, pp. 421–440.

Waring, G. A. 1908. Geology and water resources of a portion of south-central Oregon. U. S. Geol. Surv. Water-Supply Paper 220. 86 pp.

Wood, H. E., et al. 1941. Nomenclature and correlation of the North American continental Tertiary. Bull. Geol. Soc. Amer., vol. 52, pp. 1–48.

PLATES



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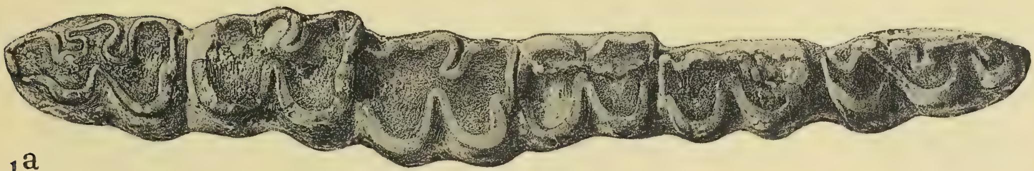

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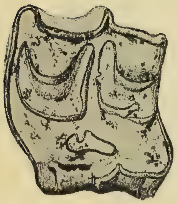

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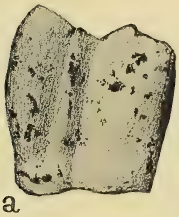

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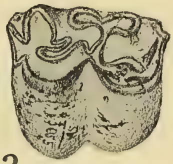

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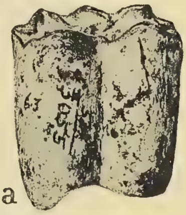

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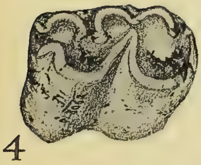

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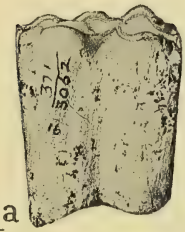

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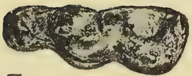

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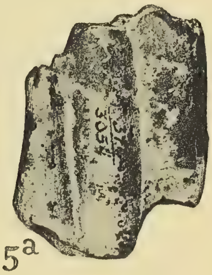

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Figs. 1, 1*a*. *Merychippus* cf. *campestris* Gidley. No. 3207, upper and lower cheek-tooth series, occlusal views.

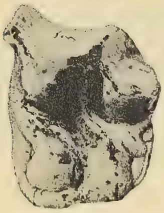
Figs. 2, 2*a*. *Merychippus* cf. *campestris* Gidley. No. 3084, P^4, occlusal and lateral views.

Figs. 3, 3*a*. *Merychippus* cf. *campestris* Gidley. No. 3055, P_3, occlusal and lateral views.

Figs. 4, 4*a*. *Merychippus* cf. *campestris* Gidley. No. 3062, M_1, occlusal and lateral views.

Figs. 5, 5*a*. *Merychippus* sp. No. 3054, M_3, occlusal and lateral views.

Calif. Inst. Tech. Vert. Pale. Coll. × 1
Beatty Buttes Miocene, Oregon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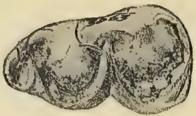
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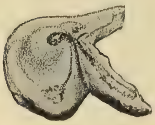
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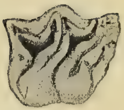
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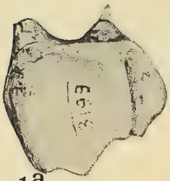
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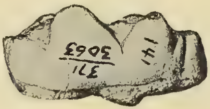

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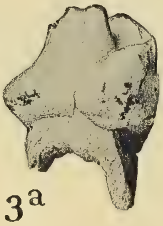
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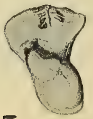
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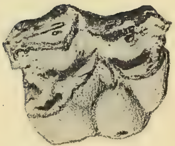
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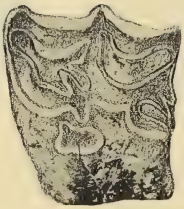
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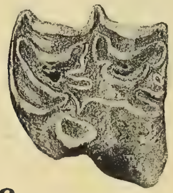
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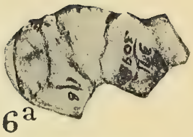
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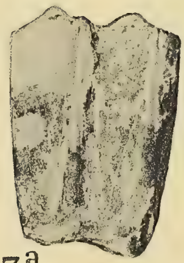
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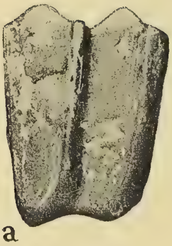
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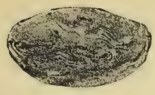
Figs. 1, 1*a*. *Hypohippus* near *osborni* Gidley. No. 3199, P^3, occlusal and lateral views.
Figs. 2, 2*a*. *Hypohippus* near *osborni* Gidley. No. 3063, M_3, occlusal and lateral views.
Figs. 3, 3*a*. *Parahippus* cf. *avus* (Marsh). No. 3064, M_1?, occlusal and lateral views.
Fig. 4. *Archaeohippus* cf. *ultimus* (Cope). No. 3061, upper cheek tooth, occlusal view.
Fig. 5. *Archaeohippus* cf. *ultimus* (Cope). No. 3203, fragment of upper cheek tooth, occlusal view.
Figs. 6, 6*a*. *Merychippus isonesus* (Cope). No. 3096, Dp^4, occlusal and lateral views.
Figs. 7, 7*a*. *Merychippus isonesus* (Cope). No. 3047, P^4, occlusal and lateral views.
Figs. 8, 8*a*. *Merychippus isonesus* (Cope). No. 3049, M^1, occlusal and lateral views.

Calif. Inst. Tech. Vert. Pale. Coll. × 1
Beatty Buttes Miocene, Oregon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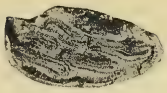
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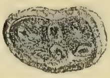
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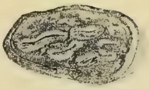
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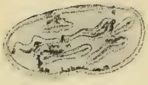
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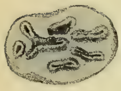
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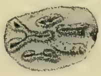
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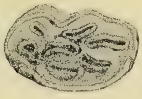
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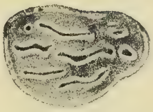
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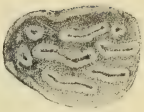
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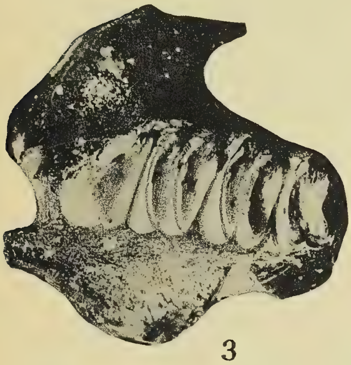
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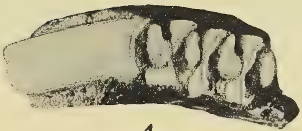
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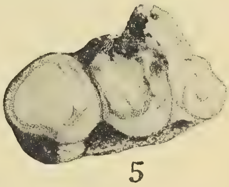
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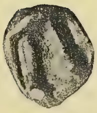
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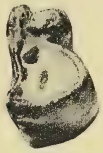
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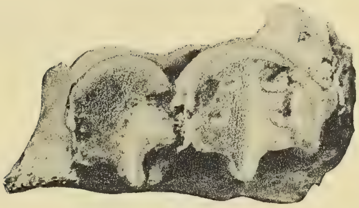
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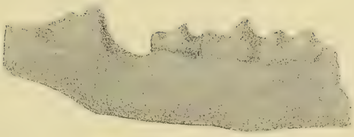
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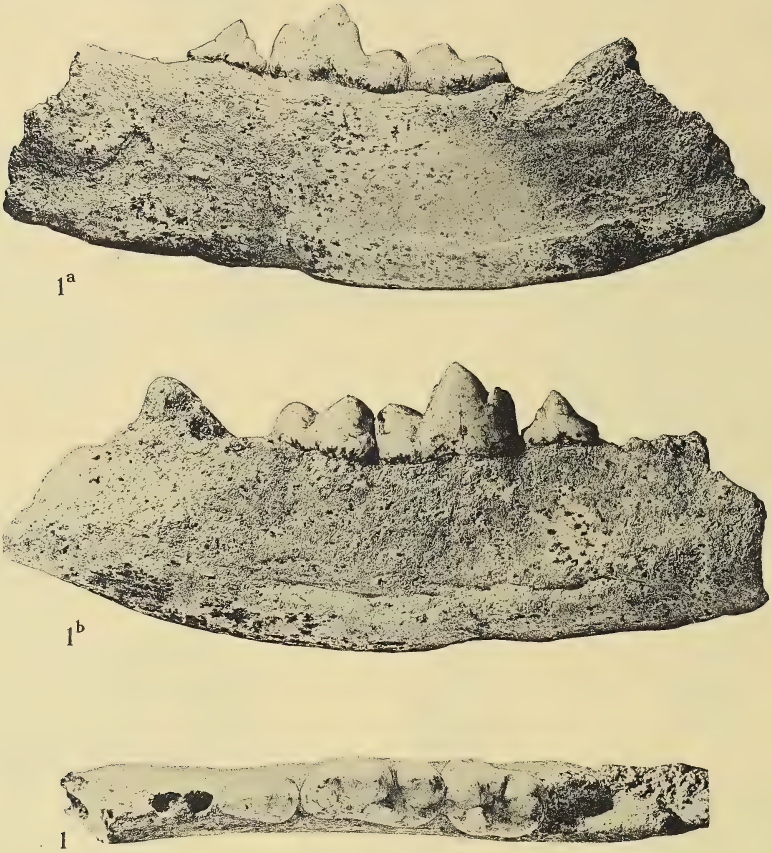
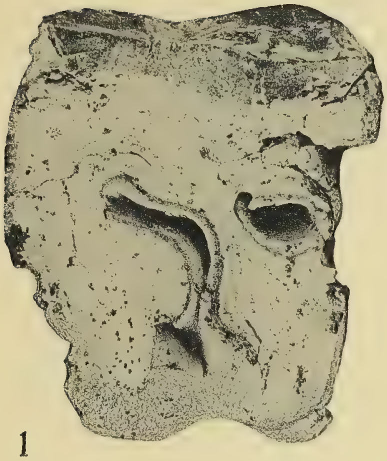
FIGS. 1–1*d*. *Mylagaulus* cf. *laevis* Matthew. Nos. 3070A–E, 5 specimens of P_4, occlusal views.
FIGS. 2–2*d*. *Mylagaulus* cf. *laevis* Matthew. Nos. 3069A–E, 5 specimens of P^4, occlusal views.
FIG. 3. *Oreolagus* (?), n. sp. No. 3074, P^3–M^2, occlusal view.
FIG. 4. *Oreolagus* (?), n. sp. No. 3088, M_1–M_2, occlusal view.
FIG. 5. *Sciurus* sp. No. 3078, P^4–M^1, occlusal view.
FIG. 6. *Sciurus* sp. No. 3077A, M^1, occlusal view.
FIG. 7. *Liodontia* cf. *alexandrae* (Furlong). No. 3082A, P_4, occlusal view.
FIG. 8. *Liodontia* cf. *alexandrae* (Furlong). No. 3083, P^3–M^1, occlusal view.
FIG. 9. Insectivore, possibly erinaceid. No. 3068, right ramus with M_1–M_3.

Calif. Inst. Tech. Vert. Pale. Coll. Figs. 1, 2 × 2; figs. 3–9 × 5
Beatty Buttes Miocene, Oregon



Figs. 1, 1*a*, 1*b*. *Amphicyon frendens* Matthew. No. 3192, right ramus with P4–M2, occlusal, internal, and external views.

Calif. Inst. Tech. Vert. Pale. Coll. × 0.5
Beatty Buttes Miocene, Oregon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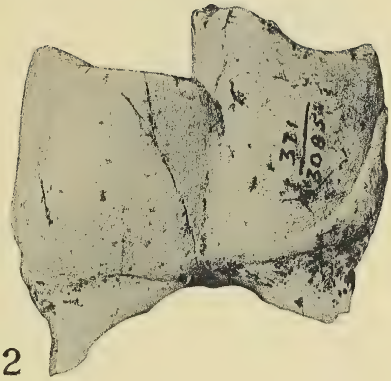

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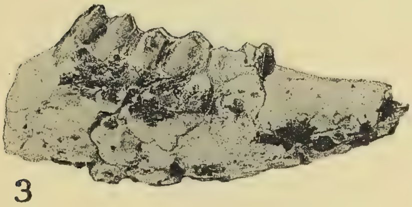
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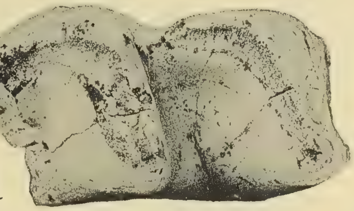
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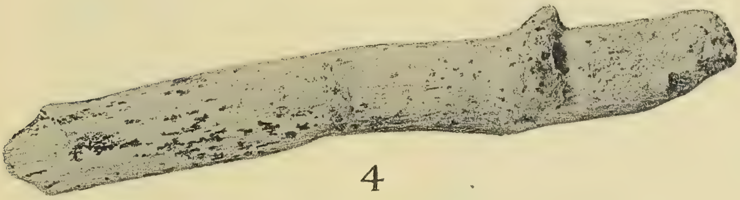
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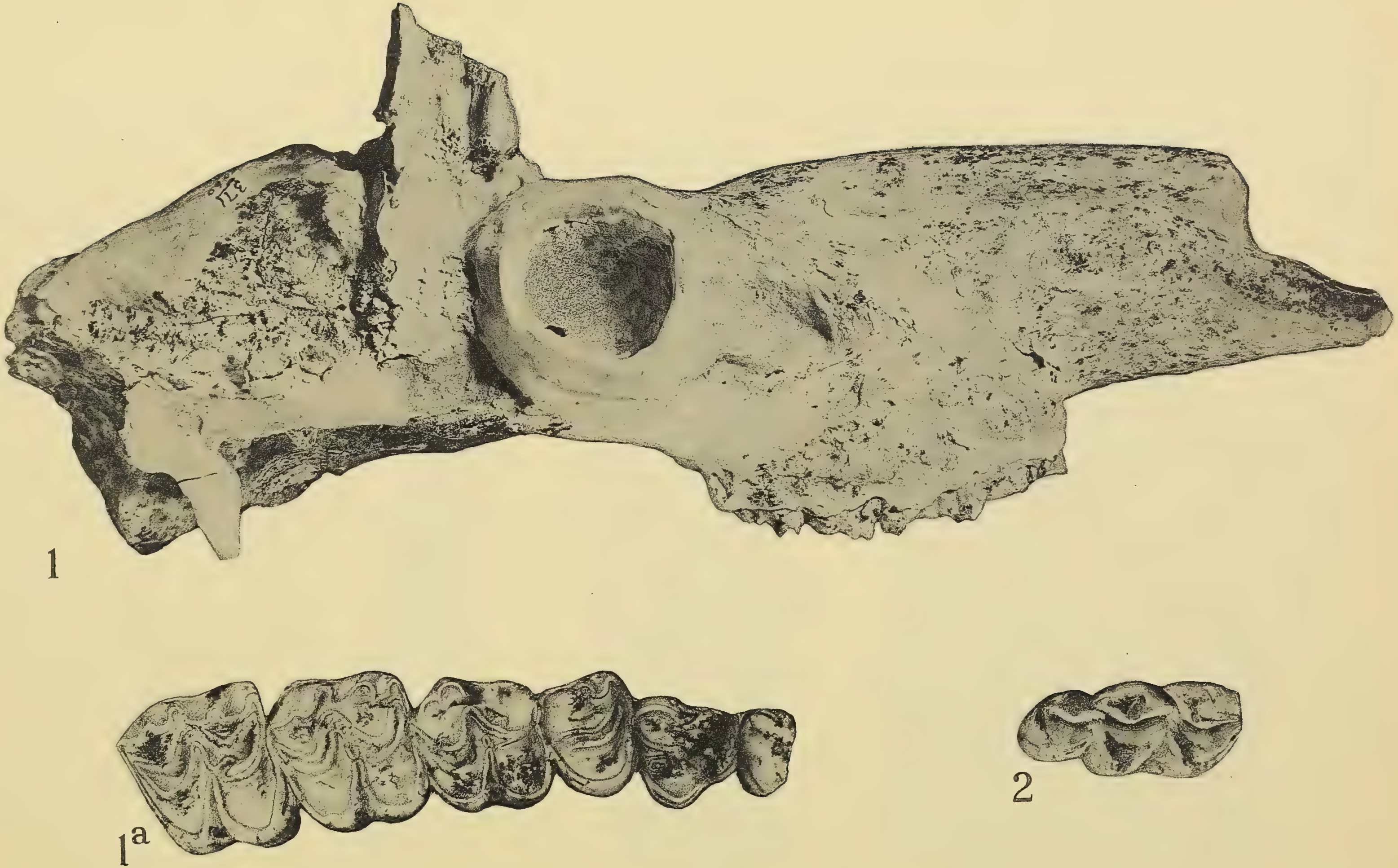
Fig. 1. *Aphelops* sp. No. 3206, P^4?, occlusal view.
Figs. 2, 2*a*. *Aphelops* sp. No. 3085, M_1?, occlusal and lateral views.
Fig. 3. *Merycodus,* possibly n. sp. No. 3066, right ramus with P_4–M_2, lateral view.
Fig. 4. *Merycodus,* possibly n. sp. No. 3194, horn core.

Calif. Inst. Tech. Vert. Pale. Coll. × 1
Beatty Buttes Miocene, Oregon



Figs. 1, 1*a*. *Dromomeryx borealis* (Cope). No. 3060, skull and right cheek-tooth series. Fig. 1, lateral view; fig. 1*a*, occlusal view.

Fig. 2. *Dromomeryx borealis* (Cope). No. 3065, M_3, occlusal view.

Calif. Inst. Tech. Vert. Pale. Coll. Fig. 1 × 0.5; figs. 1*a*, 2 × 1
Beatty Buttes Miocene, Oregon

VII

Generic Identification of the Pleistocene Antelope from Rancho La Brea

E. L. Furlong

With three plates

[ISSUED JANUARY 25, 1946]

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Generic Identification of the Pleistocene Antelope from Rancho La Brea

INTRODUCTION

When the diminutive antelope from the Pleistocene asphalt of Rancho La Brea was originally described by Taylor (1911), comparison with Matthew's genus *Capromeryx* was of necessity limited in scope. Jaw and skeletal remains of the former were available, but only an incomplete ramus with full cheek-tooth dentition comprised the Nebraskan type. Indeed, no adequate comparison between the lower cheek teeth of these forms could be made, for whereas only milk teeth are present in the one form, permanent teeth occur in the other.

Assignment of the Rancho La Brea species to *Capromeryx* was therefore tentatively made by Taylor, and was in part based upon the fact that the Californian form and *Capromeryx* showed a similar size relation to the modern pronghorn antelope. At the time of Taylor's description, *Capromeryx* was regarded as coming from Pleistocene beds in Nebraska.

Subsequent authors, following Chandler (1916), definitely regarded the extinct asphalt species as belonging to the genus *Capromeryx*. The correctness of this determination was first questioned by Hesse (1935). Later, Stirton (1938) discussed more fully the reasons why the Californian and Mexican species could not be assigned to *Capromeryx*.

A restudy of the material of the small antelope from Rancho La Brea has convinced the writer of the soundness of the views presented by Hesse and Stirton. The species *minor* is therefore placed in a new genus.

Breameryx, n. gen.

Type specimen. No. 12523, Univ. Calif. Vert. Pale. Coll., a left ramus with milk teeth, originally described as *Capromeryx* (?) *minor* Taylor.

Plesiotype. No. 1126, L. A. County Mus. Vert. Pale. Coll., a mounted skeleton.

Locality and age. Rancho La Brea Pleistocene.

Generic characters. Premolars more hypsodont than in *Capromeryx;* P_3 with single enamel indentation on lingual side of crown. Alveolar measurement of cheek teeth (P_2–M_3 inclusive) shorter than in the Nebraskan antelope. Third or posterior lobe in M_3 relatively longer; ramus of mandible not so elongated as in *Capromeryx furcifer.* Skull relatively broad in comparison with length; orbits large and tubular; bullae strongly expanded. Horn cores consisting of a short spurlike front prong and a distinctly taller hind prong, which is rounded in cross section. The two prongs are closely situated, end in points, and arise from a common base or pedestal. The latter outgrowth of the frontal is above the laterally expanded supraorbital rim. Limb elements slender and elongated. Five species have been described and are here referred to *Breameryx.* These are:

B. minor (Taylor); Rancho La Brea, California.
B. mexicana (Furlong); Tequixquiac, Mexico.
B. arizonensis (Skinner); NW. of Papago Cave, Arizona.
B. gidleyi (Frick); Curtis Flat, Arizona.
B. minimus (Meade); West Texas.

Only future studies of larger collections will decide whether or not all these forms are valid species. In view of the wide range of the modern *Antilocapra americana,* it seems at least possible that the specific divergencies within the genus *Breameryx* have been overemphasized.

No. Z8511, L. A. County Mus. Vert. Pale. Coll. (pl. 2, figs. 3, 3*a*), is a right ramus of the mandible, almost identical in size with a specimen of *B. mexicana,* no. 3243, Calif. Inst. Tech. Vert. Pale. Coll., from Tequixquiac, Mexico. The teeth are strongly hypsodont in both. In the jaw from Rancho La Brea the ascending ramus arches rather abruptly in an upper posterior direction from the level of M_3. The coronoid process extends over the buccal side of the condyle and terminates on a line with the posterior margin of the broadly expanded angle. The posterior part of the jaw below the condyle is somewhat constricted and measures 28.2 mm. in depth. From this region the lower margin extends forward to the anterior end of the diastema, where the jaw is only 9 mm. deep.

In the type of *B. minor,* no. 12523 U.C. (pl. 2, figs. 1, 1*a*), the milk teeth are hypsodont. In an older fawn, represented by specimen no. 19933 U.C., the mental foramen is elongate and the diastema is relatively short, two characters that were previously noted in *B. mexicana.* In *B. minor* the lingual faces of the lower premolars lack the pronounced styles seen in *Capromeryx.* In P_4 the transverse diameter of the posterior part of the tooth is not so great as in *Capromeryx,* and conforms to the narrower width of the molars in *Breameryx.* In the premolars the re-entrant folds on the lingual side are shallow. In contrast, P_4 in *Capromeryx* has a deep lingual inflection which aids in demarcating an anterior lobe from shallower inflections on the buccal face of the tooth in the posterior third of the crown. The crown pattern of P_4 in *Merycodus hookwayi* is much like that in *Capromeryx,* but smaller, with lingual infolds much deeper and dividing the crown into three rather than two parts. In comparison with *Breameryx,* the premolar teeth seen in ramus no. 713 C.I.T. of *M. hookwayi* and in ramus no. 1298 C.I.T. of *M. loxocerus* are almost brachyodont, yet they occupy a space which closely approximates that of the alveoli in the former. Since the teeth have shallow roots, the ramus is slender. The diastema is relatively longer, and the ascending ramus rises less abruptly than in *Breameryx.* Morphological comparison between specimens of *Capromeryx* and *Breameryx* gives small evidence of close relationship other than in those generalized characters common to the antilocaprid group.

In view of the variability caused by difference in age of individuals and condition of crown wear in dentitions, certain allowances must be made in the correlation of size and pattern of teeth. It is apparent, however, that antilocaprid genera differ decidedly in length of the cheek-tooth series, and in length of diastema. In the type ramus of *Capromeryx furcifer* the premolar-molar length is 55 mm.; *Breameryx mexicana* and *B. minor* show equal lengths of 47.0 mm. Nine individuals of *Merycodus loxocerus* average 44.9 mm. in length. The rami of 10 mature individuals of *Stockoceros* have an average measurement of 66.9 mm. Each genus apparently has a fairly constant anteroposterior length of the lower cheek-tooth series. The length of diastema also varies between one genus and another, with other concomitant changes in the morphology of the jaws.

No *Breameryx* horn cores associated with dentitions have so far been recorded from undoubted Pliocene strata. There probably is a transitional stratigraphic zone between the Pliocene and Pleistocene, in which evidence may be found linking the early antilocaprids in closer relationship. The kinds of horn cores seen in skulls of *Cosoryx* and *Merycodus* from the Miocene and Lower Pliocene may have given rise to some of the distinctive horn-core structures of the later Cenozoic. With the passing of Quaternary time in North America came the extinction of all the Antilocapridae except *Antilocapra americana,* with simplified type of horn core.

Horn cores of Recent *A. americana* show diversity in their shape. Some cores are modified to an extreme degree from the norm, and if found fossil unassociated with skeletal parts might be considered as presenting structural evidence of specific or even generic value.

As in the case of *A. americana* with its former wide geographical range, *Breameryx,* on the basis of remains so far discovered, had an extensive distribution during Pleistocene time. *Breameryx,* like *A. americana,* probably lived in a plains environment, but was not confined to the high plains. In the region about Rancho La Brea it occupied a habitat in which grasslands were interspersed with clumps of brush and trees.

Conclusions

A review of available specimens of *Capromeryx* (?) *minor* and of the literature describing this antilocaprid makes it necessary to distinguish the asphalt form generically from *Capromeryx.* The name *Breameryx* is therefore proposed. Five species referred by authors to *Capromeryx* may belong to *Breameryx.* Matthew's type species *Capromeryx furcifer* is apparently from the Pliocene, as are also the species *C. altidens* and *C. texanus.* The stratigraphic range of *Breameryx* lies within the Pleistocene.

Bibliography

Chandler, A. C. 1916. Notes on *Capromeryx* material from the Pleistocene of Rancho La Brea. Univ. Calif. Publ., Bull. Dept. Geol., vol. 9, no. 10, pp. 111–120.

Frick, Childs. 1937. Horned ruminants of North America. Bull. Amer. Mus. Nat. Hist. 669 pp.

FURLONG, E. L. 1925. Notes on the occurrence of mammalian remains in the Pleistocene of Mexico, with a description of a new species *Capromeryx mexicana.* Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 15, no. 5, pp. 137–152.

——— 1943. The Pleistocene antelope, Stockoceros conklingi, from San Josecito Cave, Mexico. Carnegie Inst. Wash. Pub. 551, I, pp. 1–7.

GAZIN, C. LEWIS. 1942. The late Cenozoic vertebrate faunas from the San Pedro Valley, Arizona. Proc. U. S. Nat. Mus., vol. 92, no. 3155, pp. 475–518.

HESSE, C. J. 1935. New evidence on the ancestry of *Antilocapra americana.* Jour. Mammal., vol. 16, pp. 307–315.

——— 1936. A Pliocene vertebrate fauna from Optima, Oklahoma. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 24, no. 3, pp. 57–70.

MATTHEW, W. D. 1904. Complete skeleton of *Merycodus.* Bull. Amer. Mus. Nat. Hist., vol. 20, art. 7, pp. 101–129.

MEADE, GRAYSON E. 1942. A new species of *Capromeryx* from the Pleistocene of west Texas. Bull. Texas Archeol. and Paleontol. Soc., vol. 14. 8 pp.

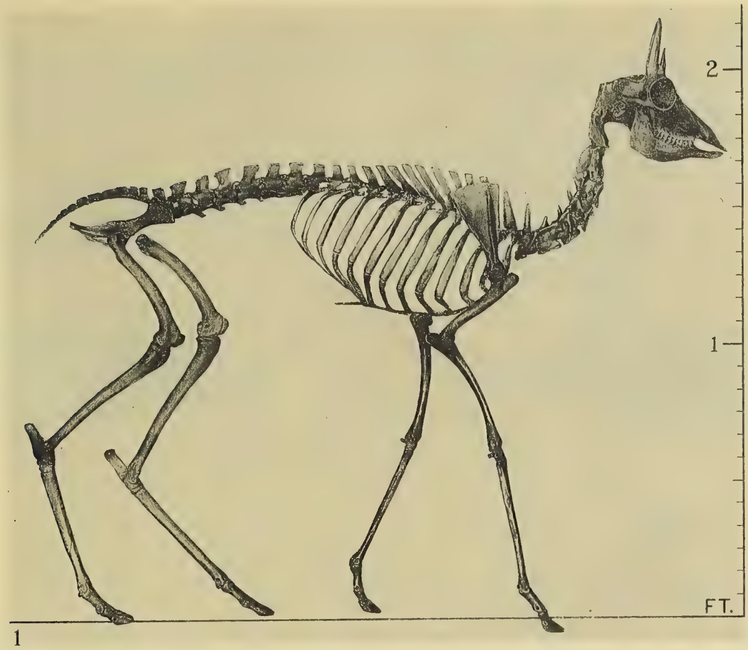
SKINNER, MORRIS F. 1942. The fauna of Papago Springs Cave, Arizona, and a study of *Stockoceros;* with three new antilocaprines from Nebraska and Arizona. Bull. Amer. Mus. Nat. Hist., vol. 80, pp. 143–220.

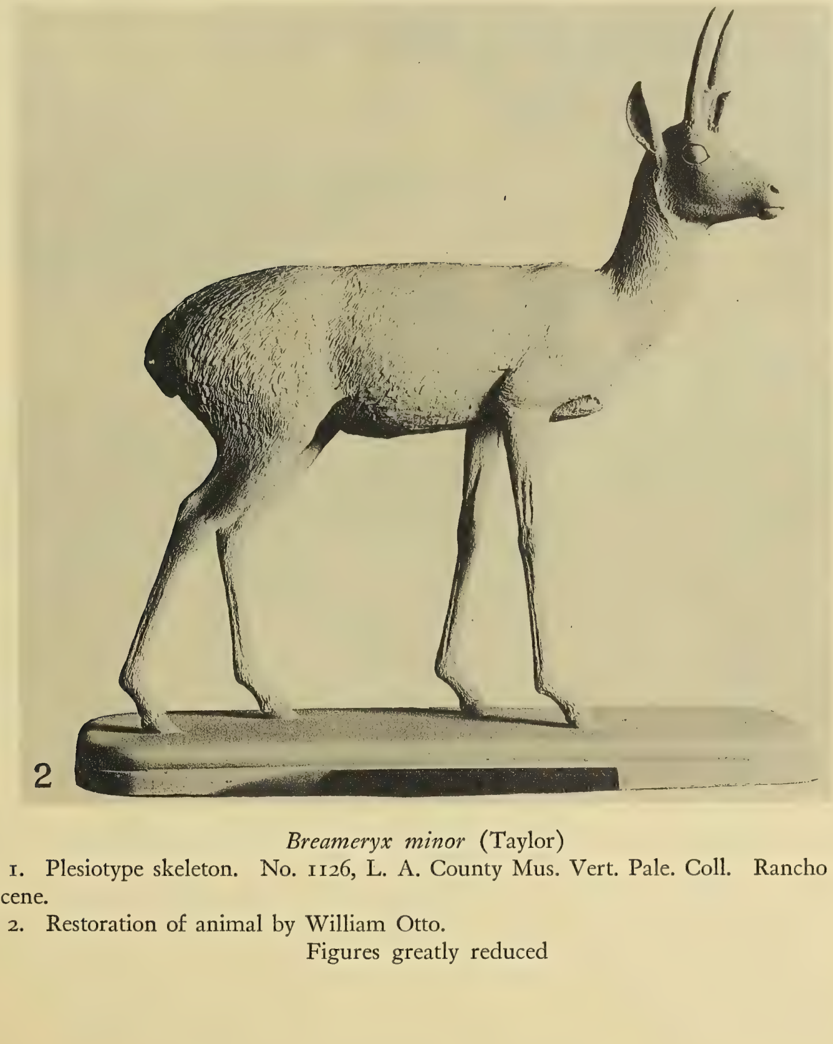
STIRTON, R. A. 1938. Notes on some late Tertiary and Pleistocene antilocaprids. Jour. Mammal., vol. 19, pp. 366–370.

STOCK, CHESTER. 1932. A further study of the Quaternary antelopes of Shelter Cave, New Mexico. Los Angeles Mus. Publ. No. 3, pp. 1–45.

TAYLOR, W. P. 1911. A new antelope from the Pleistocene of Rancho La Brea. Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, no. 10, pp. 191–197.

PLATES



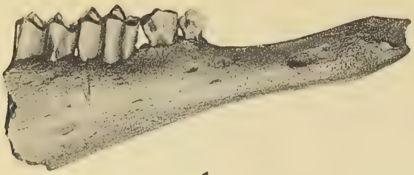


Breameryx minor (Taylor)

FIG. 1. Plesiotype skeleton. No. 1126, L. A. County Mus. Vert. Pale. Coll. Rancho La Brea Pleistocene.

FIG. 2. Restoration of animal by William Otto.

Figures greatly reduced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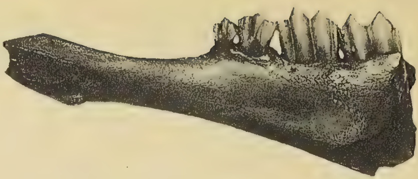
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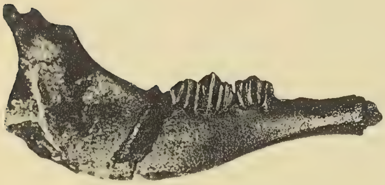
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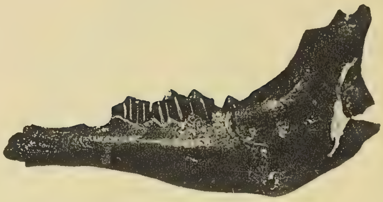
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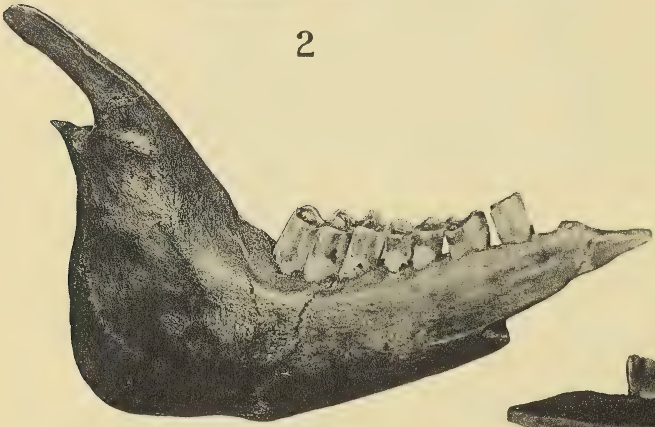
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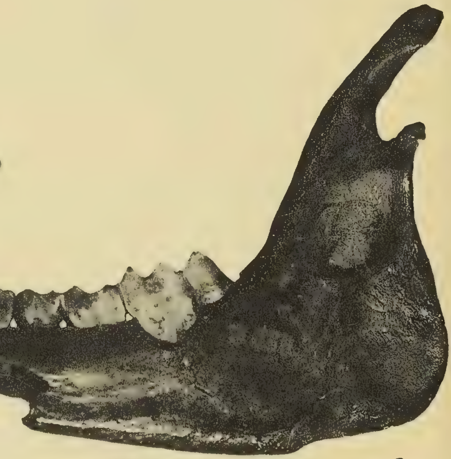
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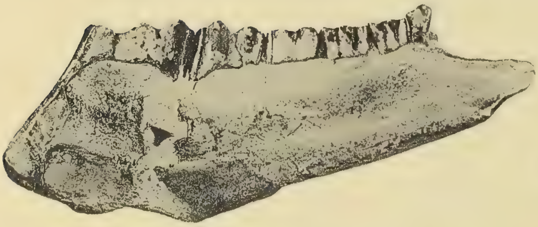
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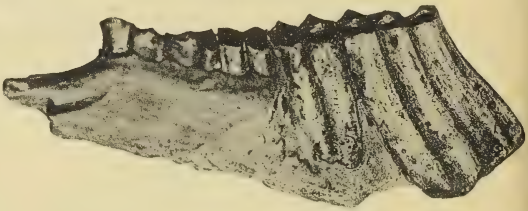
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Breameryx minor (Taylor)

FIGS. 1, 1*a*. Type ramus, buccal and lingual views. No. 12523, Univ. Calif. Vert. Pale. Coll.

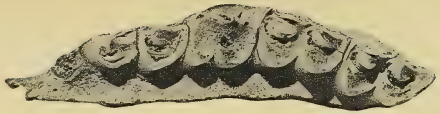
FIGS. 2, 2*a*. Part of ramus of fawn. No. 19977, Univ. Calif. Vert. Pale. Coll.

FIGS. 3, 3*a*. Part of adult ramus, showing hypsodont dentition, ascending ramus, and angle of jaw. No. Z8511, L. A. County Mus. Vert. Pale. Coll. Rancho La Brea Pleistocene.

Capromeryx furcifer Matthew

FIGS. 4, 4*a*. Cast of type ramus, buccal and lingual views, showing character of the teeth.

Figures approximately natural size



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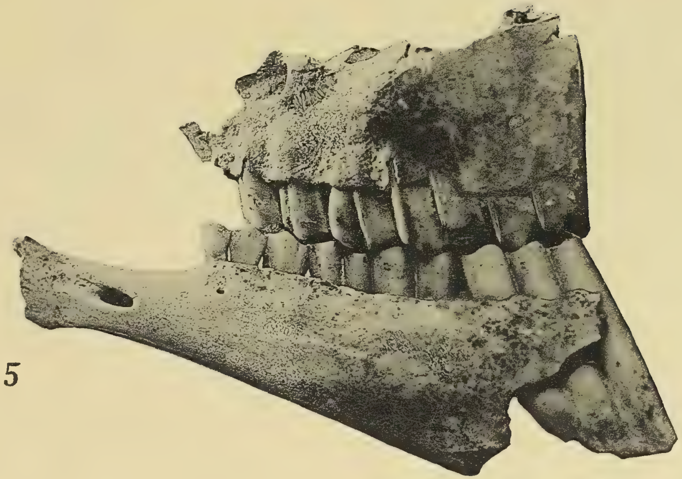

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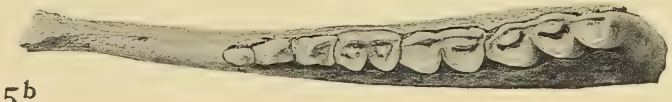

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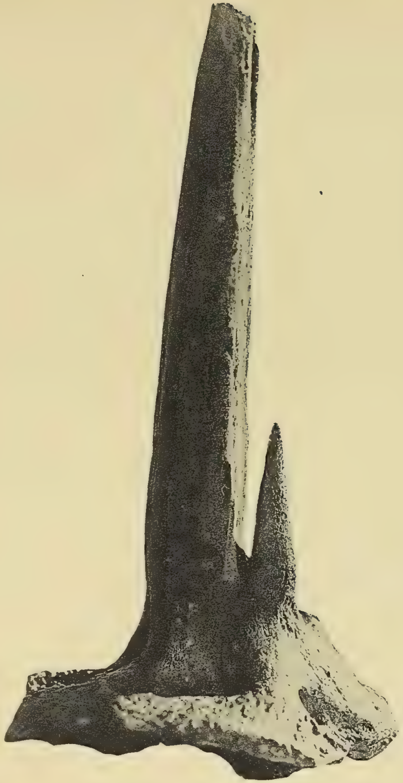

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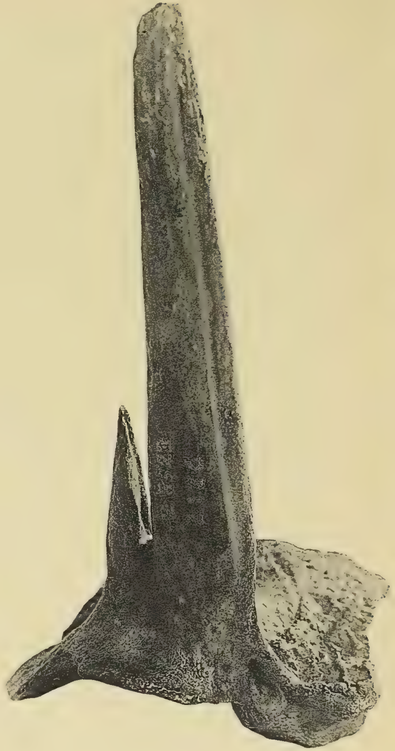

6a

Breameryx mexicana (Furlong)

Figs. 5, 5*a*, 5*b*. Parts of left maxillary and ramus, showing side and crown views of teeth. No. 3243, Calif. Inst. Tech. Vert. Pale. Coll. Pleistocene, Tequixquiac, Mexico.

Breameryx minor (Taylor)

Figs. 6, 6*a*. Right horn core, orbital and sagittal views. No. 8523, L. A. County Mus. Vert. Pale. Coll. Rancho La Brea Pleistocene.

Figures approximately natural size

CONTRIBUTIONS TO PALEONTOLOGY

VIII

A Review of the Pleistocene Birds of Fossil Lake, Oregon

HILDEGARDE HOWARD

With two plates

[ISSUED JANUARY 25, 1946]

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A Review of the Pleistocene Birds of Fossil Lake, Oregon

Introduction

In the latter part of 1942 a new collection of fossil bird bones from the Fossil Lake deposits of Oregon was made available to the writer through the courtesy of Dr. Ira S. Allison, of Oregon State College. The material was collected by Dr. Allison from 1939 to 1941, in the course of a geologic study of the area for the Carnegie Institution of Washington.

When the study of these bones was begun, it soon became obvious that, in order properly to evaluate the collection, it would be necessary to review the earlier material from Fossil Lake as well. Many species previously listed did not appear in the later material, and questions arose concerning relationships of some of the extinct forms. In the last century, and even within recent years, large series of modern bones were not available for comparison. The wide range of variation which often exists among members of certain species was not recognized, nor were the cases of overlapping of characters between different species always apparent. Consequently, it was natural that in the large assemblage of fossil bones which formed the basis of Cope's (1878, 1889*a*, 1889*b*) and Shufeldt's (1892, 1913) studies of Fossil Lake, many errors of identification should have occurred.

Although even now our modern comparative series of skeletons leaves much to be desired, we have, in most instances, from three to ten modern skeletons of the more significant species. This is in contrast with the one or two, and sometimes none at all, which were available to Cope and Shufeldt. In the hope, therefore, that further study would clarify many points and perhaps rectify errors, the writer enlisted the aid of the institutions in which the older collections are now housed. As a result, it has been possible to have at hand for study the early collections of Fossil Lake bird material from the University of Oregon (Condon collection, 1877); the American Museum of Natural History (Cope collection, 1877–1879); the United States National Museum (collected by Russell and Day, 1882–1883); and the University of California (collected by Annie M. Alexander party, 1901). To these are added two other small collections not heretofore reported upon: one from the University of California at Los Angeles (collected by Stock and Furlong, 1923–1924), and one from the California Institute of Technology (Stock and Furlong, 1927–1931). This material has been loaned by courtesy of the institutions named and through the efforts of Dr. Warren D. Smith, Mrs. Rachel Nichols, Dr. Alexander Wetmore, Mr. Ruben Stirton, Dr. Loye Miller, and Dr. Chester Stock. Casts of Cope's and Shufeldt's types have been generously made available by Mrs. Nichols, of the American Museum of Natural History, and in most instances have been examined in lieu of the original type specimens.

With all the fossil bird material known to have been taken from the Fossil Lake beds thus available for study, it has seemed advisable to treat the assemblage as a whole. Therefore, the review (and revision) of the older material is incorporated in a general survey of the entire avifauna, and no attempt has been made to discuss the contents of the new collections separately.

An endeavor has been made to rectify errors of previous identification where possible, but it has been impossible to present a detailed account of all revisions of identification of individual specimens. Usually several bones, formerly assigned to one species, bear the same catalogue number, and where these specimens have had to be separated and reassigned, a detailed explanation would prove more complicated than valuable. Many changes are indicated, however, and wherever feasible, the location (as to collection) of newly identified specimens is noted. To avoid repetition of the institution names when specimen numbers or references are given, the following abbreviations have been used:

AMNH, American Museum of Natural History (Cope collection)
CIT, California Institute of Technology
OSC, Oregon State College
UCLA, University of California at Los Angeles
UCMP, University of California Museum of Paleontology
UO, University of Oregon (Condon collection)
USNM, United States National Museum

Much of the modern comparative skeletal material used is in the collections at the Los Angeles County Museum. However, Dr. Alden H. Miller, of the University of California, Berkeley, Dr. Loye Miller and Mr. Adriaan van Rossem, of the University of California at Los Angeles, and Dr. Wetmore, of the U. S. National Museum, have kindly loaned additional specimens as needed.

I wish to take this opportunity to thank those already named who have made both fossil and recent material available. I should like, also, to express my appreciation to Mr. Malcolm Jollie, of the Museum of Vertebrate Zoology, for preparing a list of measurements of the 67 coot skeletons in the collections of that institution; to Mr. George Willett, curator of ornithology, Los Angeles County Museum, for many helpful discussions concerning modern birds of the Oregon desert region; and to Dr. Chester Stock, who has generously provided information concerning his own field investigations at Fossil Lake, and has given me the advantage of his counsel throughout this undertaking.

Historical Review

The Pleistocene bone-bearing deposits of Fossil Lake are located about 5 miles from Christmas Lake and 25 miles northeast of Silver Lake, in the Oregon desert region. Some confusion has arisen in the terminology of different authors as applied to the locality, the names Silver Lake, Christmas Lake, and Fossil Lake all being used. A careful study of the writings of the early workers in the field leads to the conclusion that all terms refer to the same deposits, namely, those of the small dry lake bed lying in longitude 120° 30′ west, latitude 43° 20′ north. (See Elftman, 1931, p. 1.)

According to Russell (1884, pp. 459–460), the locality is in the northern extension of an ancient lake which flooded the Silver Lake and Christmas Lake valleys in the Pleistocene. It lies specifically in the Christmas Lake Valley, as defined by Waring (1908, p. 59), but, at the same time, if Russell's conjectures are correct, the entire region might have been termed the Silver Lake region.

The fossil deposits were discovered by Governor Whiteaker of Oregon, in 1876 (McCornack, 1920, p. 16), but the first scientific collection was made by Thomas Condon in 1877. The description of Condon's trip is recorded in his journal, reproduced in his biography (McCornack, 1928, pp. 196–202). He described the locality (*ibid.,* p. 201) as being "an apparently circular depression four or five miles across, with some grass and tules in its lowest portions and in the middle a small pond or lake . . . The depression is bordered with a line of sand dunes formed unquestionably from sands blown from the bed of the lake that once occupied the whole of this basin. It is the blowing out of this sandy sediment which exposes the fossils in its depth."

With regard to the fossils which he collected, Condon stated (*ibid.,* p. 202), "The rarest and most valuable fossils collected on this expedition were the eighty bird bones which were unusually perfect and in a fine state of preservation."

Condon was followed later in the same year by Charles H. Sternberg, who collected for E. D. Cope. Sternberg it was who first bestowed upon the locality the name "Fossil Lake" (Sternberg, 1909, p. 158). His description of the locality (*ibid.,* pp. 158–159) accords closely with that written by Condon.

In 1879, Cope himself visited the area. As he was conducted to the site by Charles Whiteaker, son of the governor of Oregon, who had also been Condon's guide, there is no doubt that he reached the same locality, though his description shows the lake to have been completely dry at this time (Cope, 1889*b,* pp. 977–980).

In 1881–1882, I. C. Russell conducted a geological reconnaissance of southern Oregon and collected a few fossils, including one bird bone now in the collections of the U. S. National Museum. His description of the location of the fossil beds (1884, p. 460) again agrees with the previous reports. A few other bird bones, now in the U. S. National Museum, were collected the following year by William Day. For this trip no record is at hand, but there is no reason to believe that the locality was different. The term Christmas Lake is used on the specimen labels for both Russell's and Day's collections, whereas Condon and Cope used the name Silver Lake, or Silver Lake region, though Cope also introduced Sternberg's term Fossil Lake. All these early collectors apparently used Button's Ranch, near Christmas Lake, as headquarters, and the name appears on some of the specimen labels.

Subsequent visits were made to the fossil beds by parties from the University of California (Annie M. Alexander party, 1901; Chester Stock and E. L. Furlong, 1923–1924), California Institute of Technology (Stock and Furlong, 1927–1931), and Oregon State College (Ira S. Allison, 1939–1941). All these collectors have referred to the deposit as Fossil Lake.

A wealth of fossil material has been assembled as a result of the work of these many collectors. Several species of mammals and fishes have been recorded in addition to the birds which are the subject of the present study.

The early collections of bird bones were first reported on by Cope (1878, pp. 386–389). At this time he listed ten species, three of which he described as new to science. No illustrations of the extinct species were given, although characters were distinctly delineated by word, and measurements were included. Cope's list follows (*ibid.*, p. 389):

"*Podiceps occidentalis*
Podiceps near *californicus*
Podilymbus podiceps
Graculus macropus, sp. nov.
Anser hypsibatus, sp. nov.
Anser canadensis
Anser albifrons gambeli
Anser near *nigricans*
Cygnus paloregonus, sp. nov.
Fulica americana"

The same list was repeated in two later papers by Cope (1889*a*, 1889*b*), with the added notation "And numerous other species." He did no further detailed work on the birds, however, but turned over his collection to R. W. Shufeldt for this purpose.

Shufeldt's first study was based on specimens in the Cope and Condon collections, numbering, according to his estimate, over 1500 bones. The results of this study were published in detail in 1892, with two brief papers on the subject appearing the previous year (1891*a*, 1891*b*). As the second of these papers (1891*b*) presented short descriptions of the several species which he then declared to be extinct, each of these species takes 1891 as its date of original description. This is unfortunate, as the illustrations and complete descriptions did not appear until 1892, in his quarto monograph. The list of recorded species of birds from Fossil Lake rose to 50 with the publication of Shufeldt's papers, including 14 newly described.

In 1911, Loye Miller studied the material collected by Miss Alexander for the University of California, and added three species to the list, including one extinct form.

In 1913, Shufeldt again reviewed the avifauna of Fossil Lake, including in his study this time the small collections of Russell and Day at the U. S. National Museum, as well as the Cope and Condon material. Twenty-one species were added to the list, bringing the total of all avian species recorded from the locality to 74, 21 of which were described as extinct. This list appears near the end of the present paper, with the list as now amended. With the exception of a few revisions or comments on individual species, no further study of the birds of the locality has been published since 1913.

Discussion

In the combined seven collections from Fossil Lake, a total of 2500 bones have been given at least family identification, and over 1800 have been specifically referred. The Cope collection is by far the largest, with over 1600 bones now classified. The collection from Oregon State College includes 453 specimens; that of the University of California at Los Angeles, 124; the Condon collection, 104; that of the University of California Museum of Paleontology, 87; of the California Institute of Technology, 80; and of the United States National Museum, 20.

Of the 74 species recorded for the locality up to 1913, 25 are now eliminated. On the other hand, 17 have been added, bringing the total number of species now listed to 66 (not including the doubtfully classified small passerines). Of this number all but 7 are included in the Cope collection. The number of extinct forms has been reduced from 21 to 16. Another 2, however, are sufficiently distinct from modern forms to warrant some expression of difference, although there is too much overlap to separate them specifically. In both instances, it appears, rather, that the species have been undergoing gradual change since the Pleistocene, resulting in a blending of characters between the Pleistocene and Recent stages. This is a situation which should be expected in nature, and will probably become more and more apparent to future paleontologists as larger collections of fossil and recent skeletons become available. Some means of expressing this transition should be decided upon. Simpson's (1943, pp. 170–177) suggestion of considering overlapping forms of two geological periods as subdivisions of a "chronocline," and expressing the relationship with the trinomial, seems logical, though it may on occasion result in confusion with the trinomial designation of the geographic race. Nevertheless, the writer has chosen to apply the chronoclinal trinomial in the two instances here encountered, namely, *Aechmophorus occidentalis lucasi* and *Fulica americana minor.*

Calculation of the number of individual birds represented has been made by counting the lefts or rights of the most abundant element of each species, throughout the several collections. Though only a minimum estimate, this provides some idea of the relative abundance of the forms included. A list of the major groups, with the number of specimens, number of individuals, and number of species represented for each, follows:

Relative abundance of the represented avian orders

Order	No. specimens	No. individuals	No. species
Colymbiformes	921	86	4
Pelecaniformes	61	9	3
Ciconiiformes	26	10	4
Anseriformes	1113	150 (approx.)	25
Falconiformes	22	7	6
Galliformes	107	16	5
Gruiformes	162	24	2
Charadriiformes	70	24	13
Strigiformes	2	1	1
Piciformes	1	1	1
Passeriformes	15	8	4 (or 5)
	2500	336	68 (or 69)

COLYMBIFORMES

Owing to the great number of bones of *Aechmophorus,* grebes are exceedingly abundant in the Fossil Lake collections. Over 900 specimens represent at least 86 individuals.

Eight species of grebes, including three extinct forms, were previously recorded from this locality, but in the light of the present study, certain amendments are suggested.

Species previously recorded	*Amended list*
Aechmophorus occidentalis *Aechmophorus lucasi	Aechmophorus occidentalis *lucasi
Colymbus grisegena	
*Colymbus parvus	*Colymbus parvus
Colymbus auritus	
Colymbus nigricollis	Colymbus nigricollis
Podilymbus podiceps	Podilymbus podiceps
*Podilymbus magnus	

*Described as extinct.

Aechmophorus occidentalis lucasi Miller

Bones of large grebes are found in abundance, totaling over 800 specimens and representing at least 65 individual birds. It is immediately obvious that *Colymbus grisegena* is not represented in this assemblage. Contrary to Shufeldt's conception of the skeleton of this bird—which he did not have for comparison when recording the species (under former name, *C. holboelli,* 1913, p. 130)—it can be clearly distinguished from *Aechmophorus* in characters other than the over-all length of the separate bones.

The entire assemblage of large grebe bones can be assigned to *Aechmophorus.* Certain bones in the series are indistinguishable from the Recent *A. occidentalis.* On the other hand, there are numerous large specimens which do not fall within the present size range of the 7 or 8 modern skeletons available, or, in the case of the tarsometatarsus, within the range of measurements on some 20 skins. Among these large fossil specimens is the femur (UCMP no. 12605) described by Miller (1911, pp. 83–84, figs. 1, 2) as the type of *Aechmophorus lucasi.*

Examining the fossil series now available, it becomes evident that there is no line of demarcation between the largest and the smallest of the specimens. In the femur, for example, 63 complete bones on which length can be measured follow a normal curve from a minimum of 42 mm. to a maximum of 50.2 mm. (mean 46.5 mm.), the type of *A. lucasi* (48 mm.) falling beyond the peak of the curve. Eight bones of Recent western grebe range in size from 41.7 to 47.0 mm., with a mean of 44.3 mm. It is significant that, among the 63 complete fossil femora, not one specimen is as small as the minimum of the few available Recent birds.

Measurements of femora

	Length (mm.)			No. specimens	No. exceeding mean of Recent	No. exceeding maximum of Recent
	Max.	Mean	Min.			
Fossil	50.2	46.5	42.0	63	51 (80%)	23 (36%)
Recent	47.0	44.3	41.7	8	3 (37%)	....

Unfortunately there are only 4 specimens of fossil tibiotarsus on which the measurement of length can be made. Even in this small series, however, the largest exceeds the maximum of the 8 available Recent skeletons, and the minimum is slightly above the average for the Recent.

Measurements of tibiotarsi

	Length (mm.)			No. specimens	No. exceeding mean of Recent	No. exceeding maximum of Recent
	Max.	Mean	Min.			
Fossil	130.2	124.9	119.1	4	3 (75%)	1 (25%)
Recent	127.3	119.0	111.1	8	4 (50%)	....

In the case of the tarsometatarsus, it was possible to compare the range in size of 31 fossil bones with measurements of tarsus on 20 skins and 7 skeletons. In Miller's original description of this element in *Aechmophorus lucasi* (1911, pp. 83–84), six characters were enumerated in which this species differs from *A. occidentalis:* (1) greater length, (2) stouter shaft (greater breadth), (3) convex anterior border of shaft (revealed by greater depth of shaft), (4) narrower head, (5) narrower intercondylar tuberosity, (6) greater elevation of inner border of articular head.

The 7 skeletons of Recent *A. occidentalis* have been compared with the 31 fossil tarsi in regard to these characters. In this series, the sixth character (greater elevation of inner border of articular head) does not seem to be valid. In the other five, however, the fossil and Recent bones appear to diverge to a certain extent. That is, the fossil bones average longer, with stouter and deeper shaft; there is an indication of narrower intercondylar tuberosity and, to a less extent, narrower head in the ratio of these measurements to over-all length.

A study of the complete series of fossil tarsi and their measurements shows that 70 per cent of the bones fall above the mean of Recent *Aechmophorus occidentalis* in at least four of the five characters listed, and that 80 per cent are out of the range of *A. occidentalis* entirely in at least one of the characters. The cotype of *A. lucasi* is included in this latter group. However, although it is outside the range of *occidentalis* in only one character, it is above the average of the Recent species in three others. In length the cotype (UCMP no. 12603, 74.6 mm.) is below the mean of the fossils now at hand, and close to the average of the available series of *A. occidentalis*.

Measurements of tarsometatarsi

	Max.	Mean	Min.	No. specimens	No. exceeding mean of Recent	No. exceeding maximum of Recent
Greatest length (mm.):						
Fossil	85.8	77.6	68.7	31	23 (74%)	6
Recent	81.5	74.5	68.6	27	13 (48%)	......
Ratio, breadth of shaft to length of bone (%):						
Fossil	5.6	4.9	4.6	30	19 (63%)	12
Recent	5.0	4.6	4.3	7	4 (57%)	......
Ratio, depth of shaft to length of bone (%):						
Fossil	9.8	9.2	8.5	30	27 (90%)	12
Recent	9.3	8.7	8.2	7	4 (57%)	......
					No. below mean of Recent	No. below minimum of Recent
Ratio, breadth of head to length of bone (%):						
Fossil	18.1	16.9	15.4	26	13 (50%)	3
Recent	18.2	17.3	16.5	7	3 (42%)	......
Ratio, breadth of intercondylar tuberosity to breadth of shaft (%):						
Fossil	162	140	123	33	30 (90%)	22
Recent	170	154	146	7	4 (57%)	......

The series of 68 fossil coracoids shows less divergence from the Recent skeletons than is found in the leg bones. The fossils, however, average longer. The slenderness noted by Miller (1911, p. 84) in the cotype coracoid (UCMP no. 12604) appears to be associated with the fact that the specimen is an incompletely ossified bone of a young individual. Similar slenderness of fossil coracoids is noted only in other young specimens in the collections.

Measurements of coracoids

	Length (mm.)			No. specimens	No. exceeding mean of Recent	No. exceeding maximum of Recent
	Max.	Mean	Min.			
Fossil............	50.3	46.5	40.4	68	40 (59%)	6
Recent............	49.1	44.3	40.5	8	3 (37%)	......

The measurable series of each of the wing elements is very small, and none shows the divergence from *occidentalis* exhibited by the bones of the leg. It is possible, of course, that a larger series would show greater divergence. It is equally possible, however, that the body size and wing length may have remained fairly stable through time, with variations occurring largely in the leg elements.

Measurements of wing bones

	Length (mm.)			No. specimens	No. exceeding mean of Recent	No. exceeding maximum of Recent
	Max.	Mean	Min.			
Humerus:						
Fossil.......	124.7	118.9	110.2	6	5 (83%)	0
Recent......	128.2	116.1	108.7	8	3 (37%)	...
Ulna:						
Fossil.......	110.8	103.1	101.4	3	2 (66%)	0
Recent......	116.3	106.0	97.1	7	4 (57%)	...
Carpometacarpus:						
Fossil.......	55.3	52.1	47.9	10	5 (50%)	0
Recent......	55.3	50.4	47.0	8	3 (37%)	...

After a study of the complete assemblage of large fossil grebe bones, it becomes evident that there is but one genus *(Aechmophorus)* and one species represented. This species averages larger than *A. occidentalis* of today, especially in length of leg bones, although overlapping the Recent form in its range of variation. It is not, however, a subspecies of the Recent bird in the ordinary sense of the term. Rather, it is logical to assume that the living *A. occidentalis* is directly descended from the Pleistocene form, with no obvious break between the two. There has been no term in zoological nomenclature to express this gradation from one form to another in *time*. Simpson's (1943, pp. 170–177) recent suggestion, however, of the use of the trinomial for what he terms the subdivisions of a "chronocline" seems to provide a logical terminology.

The writer feels strongly that some notation should accompany the recording of this grebe so that its slight distinction from the living form may be apparent in the future, without necessity of reference to the details of this study. Whether or not the trinomial is the ultimate solution, it can at least be applied temporarily. It is therefore suggested that the name *lucasi* be transferred to trinomial position and that the entire series of *Aechmophorus* bones from Fossil Lake be known as *Aechmophorus occidentalis lucasi.* The characters distinguishing this chronoclinal subspecies from the Recent bird may be briefly summarized as follows: (1) relatively longer legs (36 per cent of femora, 25 per cent of tibiotarsi, and 20 per cent of tarsometatarsi longer than the maximum in Recent *A. occidentalis*); and (2) tarsometatarsi relatively broader and deeper of shaft, but narrower in the region of the proximal articulation (80 per cent of fossil tarsometatarsi are distinct from Recent *A. occidentalis* in one or more characters pertaining to length, breadth, or depth).

Colymbus parvus Shufeldt

Bones of grebe intermediate in size between western grebe and eared grebe were described by Shufeldt (1913, p. 136) as *Colymbus parvus.* Although Shufeldt's type material included 3 bones now referred to coot, and 3 others clearly belonging to some species of duck, Wetmore (1937, pp. 199–200), in his review of the species, has shown that the remaining 3 bones represent a grebe properly deserving of species distinction. Of these specimens (a nearly complete tarsometatarsus and 2 coracoids), Wetmore (*ibid.,* p. 200, figs. 14, 15) selected the tarsus as type. All show similarity to *Colymbus grisegena* except for appreciably smaller size.

The present survey has revealed 7 other specimens of a medium-sized grebe which are here assigned to *C. parvus.* The complete list of available specimens of this species follows: A nearly complete tarsometatarsus (type, AMNH no. 3570); distal end of tarsometatarsus, and proximal end of tibiotarsus (AMNH no. 3672); 2 coracoids (cotypes, AMNH no. 3570); a carpometacarpus (AMNH no. 3572A); femur and coracoid (UCMP no. 31771); and an imperfect ulna and carpometacarpus (OSC 2500/18 and 19). A distal end of femur (UCMP no. 31795) is tentatively referred to this species.

As Wetmore has already discussed the tarsometatarsus and coracoid of this species, only the remaining elements are described here.

Carpometacarpus. Measurable specimen of fossil carpometacarpus 2 mm. smaller than minimum of 4 available Recent carpometacarpi of *Colymbus grisegena.* Further distinguished from *grisegena* by greater length of distal symphysis, and flatter and straighter internal border of metacarpal 3 in region of proximal symphysis.

Femur. As the femur is badly chipped, the only exact measurements possible are breadth and depth of shaft. Breadth, 0.6 mm. less than smallest available femur of *grisegena;* depth, 1 mm. less. Inexact measurement of length from middle of tubercle above popliteal area, to proximal end, about 2 mm. less than smallest *grisegena.*

Apparent structural differences between *parvus* and *grisegena* are: greater depression on anterior face along trochanter in *parvus,* and flatter posterior surface proximally. The fragmentary state of the fossil specimen, however, makes it impossible to be certain of these features.

Ulna. A proximal end, badly chipped, clearly smaller than *grisegena,* but exact measurements impossible. Impression of brachialis anticus appears more evident on palmar face of bone than in *grisegena,* and there is less slope from palmar to internal face in this area.

Comparative measurements

	Colymbus parvus				*C. grisegena*	
	AMNH no. 3570	AMNH no. 3572A	AMNH no. 3672	UCMP no. 31771	Max.	Min
Tarsometatarsus:						
Length from lower end of hypotarsus (mm.)	47.0	....	...	....	....	....
Least breadth shaft, anteriorly (mm.)	3.0	....	3.0	....	....	....
Depth external trochlea (mm.)	5.5	....	5.0	....	....	....
Coracoid:						
Length from head to internal tip sternal facet (mm.)	35.5 and 38.0	....	...	36.4	40.6	39.1
Femur:						
Length from tubercle in popliteal area (mm.)	....	....	...	30.8	37.3	32.7
Least breadth shaft (mm.)	....	....	...	4.6	5.9	5.2
Depth shaft, middle (mm.)	....	....	...	4.8	6.7	5.8
Ratio, depth to breadth shaft (%)	....	....	...	104	113	111
Carpometacarpus:						
Length (mm.)	....	45.0	...	....	49.9	47.6
Least breadth metacarpal 2 (mm.)	....	3.1	...	....	3.3	3.0
Height metacarpal 1 (mm.)	....	7.0	...	....	7.8	7.1
Length distal symphysis (mm.)	....	7.6	...	....	7.4	6.7
Length proximal symphysis (mm.)	....	10.2	...	....	10.7	10.1
Ratio, breadth metacarpal 2 to length (%)	....	6.9	...	....	6.6	6.3
Ratio, height metacarpal 1 to length (%)	....	15.5	...	....	16.1	14.9
Ratio, length distal symphysis to length (%)	....	16.8	...	....	14.8	13.8
Ratio, length proximal symphysis to length (%)	....	22.7	...	....	22.2	21.2

Colymbus nigricollis (Brehm)

There are 67 bones of small *Colymbus* in the combined collections from Fossil Lake now at hand. These apparently represent 14 individuals, at least. All which can be definitely identified may be assigned to *C. nigricollis*. The differences between this species and *C. auritus* are not marked and it is difficult, in many instances, to separate them. On the whole, however, the bones of *auritus* are larger than those of *nigricollis*. With the exception of 2 bones, the fossil specimens are small, and fall below the size range of *auritus*. Of the 2 excepted specimens, the femur equals the minimum size of *auritus*, but falls well within the range of *nigricollis* as well. It may unquestionably be assigned to *nigricollis* on the basis of the short fibular condyle. The other bone, a coracoid, could also be referred to either *nigricollis* or *auritus* in the matter of size. The narrowness of the bone beneath the head, and the relatively shorter distance from procoracoid to head, agree more closely with *nigricollis*.

Of the 6 bones which Shufeldt assigned to *C. auritus* (AMNH no. 3564), the tarsometatarsus is unmistakably *Podilymbus podiceps* (see distinguishing characters under discussion of that species), and the 2 ulnae are not grebe. The humerus and 2 tibiotarsi are much smaller than in the smallest available skeletons of *auritus,* and fall within the size range of *nigricollis*. They are therefore assigned to this latter species.

Podilymbus podiceps (Linnaeus)

Six bones in the Cope collection were assigned by Shufeldt to the pied-billed grebe. On careful study, however, and comparison with Recent material, it becomes evident that all these belong to *Colymbus nigricollis*. They are distinguished from *Podilymbus* as follows: (1) narrower impression of brachialis anticus in the humerus, (2) shorter and stockier carpometacarpus, (3) greater distance from procoracoid to head in the coracoid, and (4) broader, more deeply excavated shaft of tarsometatarsus.

Other specimens in the collections are assignable to *Podilymbus podiceps,* however, so the species is maintained in the list of birds from Fossil Lake. In his review of Shufeldt's *"Podilymbus magnus,"* Wetmore (1937, pp. 198–199) has shown that the 3 bones of *magnus* are in reality large (probably male) specimens of *P. podiceps*. There is a great range in size between male and female in the pied-billed grebe, and, as Wetmore has indicated (*ibid.,* p. 199), only one female skeleton of *P. podiceps* was available to Shufeldt at the time the extinct species was described.

In addition to the 3 bones described as *P. magnus,* which are now assigned to *P. podiceps,* 11 other specimens may be referred to this species, 9 in the Cope collection and 2 from Oregon State College (no. 2500/15). Two of the Cope specimens (tarsometatarsi, AMNH nos. 3564B, 3566) were originally assigned to *Colymbus*. They are reclassified on the basis of the following characters: (1) Shorter and stockier than either species of small *Colymbus;* (2) upper half of broad shaft deeply excavated anteriorly, with external border of shaft forward, internal edge receding.

PELECANIFORMES

This order is only moderately represented in the Fossil Lake deposits. One pelican and one species of cormorant were recorded by Shufeldt, and another cormorant is added at this time. Only one species is represented by more than 2 specimens.

Pelecanus erythrorhynchos Gmelin

Shufeldt (1892, p. 401) tentatively recorded the white pelican on the basis of a distal end of ulna (AMNH no. 3486). Although this specimen has been found to belong to an eagle rather than a pelican, 2 other specimens are now available which are assignable to *Pelecanus erythrorhynchos*. It may therefore remain in the list of birds from the Pleistocene of Oregon.

The specimens on which the identification is now based are: an anterior part of sternum (AMNH no. 3551D, originally assigned to *Cygnus paloregonus*) and a head of a scapula (UCMP no. 31796).

Phalacrocorax macropus Cope

Cope (1878, p. 386) described this extinct species of large cormorant from 3 nearly perfect tarsometatarsi, without designating one particular specimen as the type.

Judging from his measurements, these specimens are illustrated by Shufeldt (1913, pl. 22) as figures 280, 281, and 283 (Cope's numbers 1, 2, and 3, respectively). The last specimen is the most complete and was earlier figured in two views by Shufeldt (1892, pl. 15, figs. 7, 8). Although there appears to be no previous record of the selection of this specimen from Cope's 3 as the holotype, it has been generally so regarded, and seems a proper choice.

Other specimens of *Phalacrocorax macropus* figured by Shufeldt (1892, pl. 15, fig. 6; 1913, pls. 20–23) include 5 more tarsometatarsi, 4 coracoids, 2 carpometacarpi (a third carpus figured is not cormorant), 3 vertebrae, and fragments of humerus, ulna, femur, tibiotarsus, and upper and lower mandible (all, including types, AMNH no. 3555). In addition to the 25 figured specimens, 32 more have been recognized, including other elements (AMNH nos. 3555, 3556, 3670, 3671; OSC no. 2500/20; UCLA no. 1960/3).

As was pointed out by Shufeldt, the upper mandible is heavy and short, with concave dorsal surface, characteristic of the *Phalacrocorax* subgeneric group.[1] Other elements of the skeleton also reflect relationship to this subgenus, although there are certain characters which are distinct and show a leaning toward *P. penicillatus* (subgenus *Compsohalieus*).

Coracoid. Outstanding among the distinguishing features of the cormorants is the relative distance of the anterior intermuscular line from the internal edge of the shaft, in the coracoid. In a previous paper (Howard, 1932*a*) it was suggested that this character might be of subgeneric value. Ratios of this distance relative to length of bone measured to the internal tip of the sternal facet give the following percentages: *P. carbo, P. auritus,* and *P. olivaceus* (all of subgenus *Phalacrocorax*), 15 per cent; *P. macropus,* 17–19 per cent; *P. penicillatus* (subgenus *Compsohalieus*), 19–21 per cent; *P. pelagicus* and *P. perspicillatus* (subgenus *Urile*), 21–22 per cent. In the rounded form of the procoracoid, thickened head, excavated neck region, and short, broad dorsal lip of sternal facet, *macropus* is practically identical with *auritus.* On the other hand, the fossil shows greater excavation below the head internally than in the latter species.

The other large fossil cormorant of the west coast, *Phalacrocorax rogersi* Howard (1932*a*), described from the Pliocene of Santa Barbara, California, agrees with *P. macropus* in size, but shows affinity with members of the *Urile* subgenus. In the type coracoid of the Pliocene species, the distance of the intermuscular line from the internal edge of the bone is 22 per cent of the total length, as in *pelagicus* and *perspicillatus.* Other characters of the bone, as well, show relationship to the strictly oceanic group of cormorants. The Fossil Lake *P. macropus,* on the other hand, shows closer relationship to the forms which nest inland, a fact further attested to by the presence of several incompletely ossified bones of young birds in the Oregon deposit, giving evidence of near-by nesting colonies in the Pleistocene.

Tarsometatarsus. In general appearance close to *auritus,* lacking the marked anterior projection of the distal trochleae characteristic of *penicillatus* and *pelagicus.* Details of proximal anterior surface similar to *pelagicus* in the marked intercotylar depression, with no distinct barrier separating it from the long internal ridge of the hypotarsus. A similar condition is present in *penicillatus,* but accompanying it in that species is a distinct difference in level between the posterior rim of the internal cotyla and the hypotarsus, which is not evident in the other forms.

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[1] Subgenera of *Phalacrocorax* omitted in supplement of the American Ornithologists' Union Checklist. Auk, vol. 61, p. 443, 1944.

Carpometacarpus. Broad and flat posteriorly below carpal trochlea, as in *auritus.* Internal trochlear crest less distinctly set off from shaft of bone below, and in this respect closer to *pelagicus.* Metacarpal 2, though broken in available specimens, flat and straight at both its proximal and distal ends, suggesting the condition in *auritus.* Proximal metacarpal symphysis short and unexcavated, as in *auritus.*

The carpometacarpi of *macropus* have also been compared with a cast of the same element representing the type of *Phalacrocorax idahensis* Marsh from the Upper Pliocene of Castle Creek, Idaho.[2] In size the two species are in agreement. Their structural characters, however, clearly indicate their distinctness. The outstanding points of separation are as follows: (1) Process of metacarpal 1 more prominent, more forward-projecting, and more compressed proximally (Marsh, 1870, p. 215) in *idahensis;* (2) internal trochlear crest longer and more obliquely placed in *idahensis,* suggesting the condition in *penicillatus* (*macropus* closer to *auritus* in straight, short internal crest); (3) on inner side, excavation above pisiform process greater in *idahensis,* that anterior to pisiform process shallower; (4) intermetacarpal tuberosity placed high on shaft, on a line with proximal metacarpal symphysis, in *idahensis,* more distally in *macropus.*

Other elements. The other elements are incomplete and fragmentary, but all discernible characters point toward closest relationship with *auritus,* with certain similarities to *penicillatus* in some small details.

Distal ends of humerus show irregularly excavated brachial depression characteristic of *auritus,* with deep hollowing of distal half of area.

Contour of internal side of femur beneath head resembles *auritus,* but shape of muscle scars in popliteal area, distally, suggests *penicillatus,* particularly scar immediately above internal condyle, which is long and crescent-shaped, whereas in *auritus* it forms a large papilla-like crest.

Distal end of tibiotarsus resembles *penicillatus* in long posterior crest of internal condyle, but general contour anteriorly is closer to *auritus.* External condyle excavated somewhat as in *auritus,* but posterior border more flangelike, suggesting *penicillatus.*

Articular end of lower mandible similar to *auritus;* ramus stout and smoothly rounded externally in front of articular end; pneumatic foramen on internal side, near articulation, well above lower margin of ramus; and ventral border of ramus rounding in a smooth curve up to articular end, with slight excavation bordering it internally.

Measurements (in millimeters) of Phalacrocorax macropus

Tarsometatarsus (6 specimens):	
Length	75.5–87.0
Breadth distal end	17.5–20.0
Breadth proximal end	15.7–17.4
Breadth shaft at middle	7.5– 9.2
Humerus (3 specimens):	
Greatest breadth across distal end	18.6–19.8
Coracoid (4 specimens measured for length, 5 for breadth):	
Length to internal tip of sternal end	76.5–85.5
Breadth just above procoracoid	13.3–15.2

[2] Cast made available through the courtesy of Dr. Carl O. Dunbar, of the Peabody Museum of Natural History at Yale University, and Dr. A. Wetmore, U. S. National Museum.

Measurements (in millimeters) of Phalacrocorax macropus—Continued

Femur (1 specimen for each measurement):	
Internal length	69.6
Breadth distal end	21.5
Upper mandible (1 specimen):	
Length to frontal symphysis	80.0
Tibiotarsus (1 specimen):	
Breadth across distal condyles	15.7
Sacrum (1 specimen):	
Length (approximate)	143.0
Carpometacarpus (1 specimen measured for length, 3 for other dimensions):	
Length along external edge	82.8
Depth proximal end	16.2–16.4
Height process metacarpal 1	12.0

Phalacrocorax auritus Lesson ?

In the material from Oregon State College are two bones (OSC no. 2500/21) of cormorant smaller than the extinct *Phalacrocorax macropus.* These resemble *P. auritus* in size and general characteristics, though the coracoid seems less excavated in the neck region, and in the tarsometatarsus the tendinal canal of the hypotarsus is open as in *P. macropus.* In all specimens of *auritus* or of *penicillatus* at hand, this canal is securely closed by a bony bridge. Possibly this condition could vary with the age of the bird. Certainly this tarsus cannot be assigned to the extinct *macropus;* not only is it very much too small, but the proximal end resembles *auritus,* rather than *macropus,* in the shallowness of the intercotylar depression.

No specimens of small cormorant were found in any of the other collections.

CICONIIFORMES

Bones of ciconiiforms are rare in the Fossil Lake deposits, and the majority of those which do occur belong to the Phoenicopteridae rather than to the expected Ardeidae. Three species of the latter family were recorded by Shufeldt, based on scant material in the Cope collection, but one of these now falls into synonymy. Phoenicopterid bones, though occurring in greater abundance than those of the heron group, represent a single species, described as extinct. Evidence of an additional ciconiiform species, representing the family Ciconiidae, has appeared in the course of the present study.

Ardea herodias Linnaeus

The great blue heron was recorded from a single scapula (AMNH no. 3482). It coincides with available Recent specimens of *Ardea herodias* and is apparently correctly assigned.

Botaurus lentiginosus (Montagu)

Shufeldt assigned 2 coracoids to the bittern (AMNH no. 3483), both of which agree in all particulars with available specimens of *Botaurus lentiginosus.* Two other coracoids in the Cope collection (AMNH no. 3679) and one in the Oregon State College material (OSC no. 2500/22) are also indistinguishable from this species.

The distal end of tarsometatarsus (AMNH no. 3484) designated as the type of *Ardea paloccidentalis* was described (Shufeldt, 1892, p. 411 and pl. 17, fig. 31) as being between *Casmerodias egretta* and *Leucophoyx thula* in size, with a breadth of 11 mm. across the distal trochleae. An excellent cast of the type is available for study.

It shows a downward slant of the distal end toward the internal side as in the bitterns; the trochleae are more evenly balanced in the herons and egrets. Anteriorly the middle condyle in the fossil slants toward the internal side, and on the posterior side the external flange of this trochlea continues slightly beyond the internal flange proximally, as in *Botaurus*. It is apparent, therefore, that the fossil is a bittern rather than an egret. Although in general appearance the bone seems more slender than available tarsi of Recent *Botaurus lentiginosus,* in all measurements except depth of distal end the fossil can be duplicated in Recent skeletons of that species. Particularly as the specimen is somewhat worn, it does not seem justifiable to recognize it as specifically distinct from the living American bittern. *Ardea paloccidentalis* should, therefore, become a synonym of *Botaurus lentiginosus.*

Measurements (*in millimeters*) *of tarsometatarsi*

	Breadth across distal trochleae	Breadth of shaft above distal end	Depth of distal end
Fossil (AMNH no. 3484)	11.0	5.7	6.4
Botaurus lentiginosus	10.4–12.8	5.7–6.1	6.6–7.7

Stork, species

(Plate 1, figure 7)

A single pedal phalanx (phalanx 1 of digit 2) in the University of California material (UCMP no. 31769) closely resembles specimens of *Ciconia maltha* from Rancho La Brea. As this is the only bone in the collections to show such affinity, the writer hesitates to record the presence of the La Brea stork. The relationship of the phalanx, however, is undoubtedly with the storks, rather than with the herons or flamingos.

Phoenicopterus copei Shufeldt

Eighteen bones of flamingo are present in the combined collections from Fossil Lake. On the basis of several tarsometatarsi, it is probable that at least 4 individuals are represented.

Shufeldt's material (1892, pp. 410–411 and pls. 15, 17, figs. 11, 13, 28, 29, 38) consisted of incomplete specimens of 4 tarsometatarsi, and 2 tibiotarsi, as well as a perfect coracoid, wing phalanx, toe phalanx, and quadrate (all AMNH no. 3485). To these are now added distal ends of radius and ulna from the Cope collection (AMNH no. 3680), a vertebra, scapula, and proximal end of femur from Oregon State College (OSC no. 2500/23), a pedal phalanx (UCMP no. 31788), and 2 tarsometatarsi (1 young specimen, CIT no. 137/3270; and 1 adult distal end, USNM no. 7590, originally referred to *Branta hypsibata*). Although Shufeldt made no designation of a type in his discussion of the species, the wing phalanx and a left distal end of tarsometatarsus were so named in the explanation accompanying the illustrations (1892, pl. 15, fig. 13, and pl. 17, fig. 38, respectively).

Regarding the relationships of the flamingo, Shufeldt declared (*ibid.*, p. 410) that *Phoenicopterus copei* was "closely allied to our existing *P. ruber* and slightly larger than it," and also that "the extinct form was longer winged and longer legged and toed than *P. ruber*."

When the fossil specimens are compared with Recent specimens of *P. ruber, P. antiquorum,* and *P. chilensis* now at hand, the following points become evident: The African bird, *P. antiquorum,* averages larger throughout the skeleton than either *P. ruber* or *P. chilensis,* although there is a degree of overlap. One of the 3 distal ends of fossil tarsometatarsus and the 1 measurable distal end of tibiotarsus are above the maximum size for either of the American flamingos, but fall within the range of *antiquorum*. The length of toe and wing phalanges is greater than in available specimens of any of the Recent forms compared. The length of coracoid agrees with all three species, but the distance across the furcular facet, anteroposteriorly, is greater than in either of the American forms.

One character of the distal end of the tibiotarsus appears to separate the fossil from *P. ruber,* namely, the relatively greater breadth across and between the condyles. The same condition is found in Recent specimens of *P. antiquorum* and *chilensis,* and in these forms is associated with greater lateral development of the intercotylar prominence of the tarsometatarsus. Unfortunately the proximal end of the tarsus is not available for the fossil bird; the distal end of this element shows no characters of specific value. It is surprising that Shufeldt should have named one of the tarsal specimens (along with the wing phalanx) as a type, when he selected the coracoid as the element showing the most diagnostic characters.

Characters of the coracoid are delineated as follows (Shufeldt, 1892, p. 411), the comparisons being made with *P. ruber:* "[1] In *P. copei* the summit is markedly narrower, while [2] the mesial aspect of the shaft just below it is a circumscribed, flat area. [3] The scapular process in *P. ruber* is narrow in the vertical direction,—broader in *P. copei.* [4] The distance from the anterior edge of the glenoid cavity to the anterior border of the shaft in *ruber* measures ten millimetres; in *P. copei* only eight millimetres." (The numbers have been inserted for convenience of reference.)

(1) Although there is some variation in depth of summit in the Recent forms, the fossil is relatively narrower than all. Depth, relative to length of coracoid (measured to internal tip of sternal end), 12.9 per cent in *copei,* 13.4 to 15.7 per cent in the Recent forms.

(2) and (3) These are variable characters and do not hold in a larger series of Recent forms.

(4) These measurements are here interpreted to indicate a less projected procoracoid in *P. copei.* It is difficult, however (owing to the curvature of the area), to duplicate the figures exactly. The position of the measurement as now taken gives a slightly smaller figure (7.5 mm.) for the fossil bone. This distance, relative to the anteroposterior breadth of the shaft below the furcular facet, yields the following percentages: *P. copei,* 57.5 per cent; Recent forms, 59.5–67.0 per cent.

Measurements (in millimeters) of fossil coracoid

Length to internal tip sternal end	55.2
Anteroposterior breadth furcular facet	17.0
Depth of head*	7.1
Anteroposterior breadth shaft below furcular facet	13.4
Distance between procoracoid and shaft	7.4

*Internal border of summit broken; measurement taken with calipers placed just below border on internal side (in area of furcular facet).

Comparative measurements (in millimeters) of Phoenicopterus copei and Recent flamingos

	P. copei	*P. ruber*	*P. chilensis*	*P. antiquorum*
Breadth distal end tibiotarsus	17.1	13–16	15–16	16–18
Depth distal end tibiotarsus	20.0	17–19	17–18	18–20
Breadth distal end tarsus	20.1–22.1	18–20	19–20	19–22
Length coracoid	55.2	50–56	56	52–57
Length wing phalanx	43.5	36–39	39	36–40
Length pedal phalanx	47.5	42–43	39–42	38–46

ANSERIFORMES

Bones of anseriforms outnumber those of any other order, totaling over a thousand and representing approximately 150 individual birds. To facilitate reference, the discussion of the twenty-five species appears under three major heads, Swans, Geese, and Ducks.

Swans

Four species of swans were previously recorded from the Fossil Lake deposits. In addition, the type specimen of *Anser condoni* Shufeldt, a large furcula, is also undoubtedly swan. Only one species, the extinct *Cygnus paloregonus,* was recognized by Cope; Shufeldt added *C. buccinator* and *C. columbianus,* and described another species, *C. matthewi,* as well as the so-called goose, *Anser condoni.*

Among the 157 fossil bones of swans which have now been examined, but two species can be distinguished, and the record is therefore amended here to include only *Cygnus buccinator* and one extinct form. This results in the lumping of the species previously described as *Cygnus paloregonus* Cope (1878, type tarsometatarsi), *Anser condoni* Shufeldt (1892, type furcula), and *Cygnus matthewi* Shufeldt (1913, type carpometacarpi and scapulae). As *paloregonus* was first to be described, the other two now become synonyms of that species.

Regarding *"Anser condoni,"* it is obvious that Shufeldt had no specimens of mute swan at the time he described the fossil species, and presumably knew nothing of the simplified structure of the furcula associated with the absence of looping of the trachea in some swans. The largest simple anseriform furcula available to him was that of a goose, hence the referral of the fossil furcula to the genus *Anser.*

The description of *"Cygnus matthewi"* was undoubtedly the result of Shufeldt's misconception of the size of *paloregonus.* Apparently he had become convinced that this extinct species was larger than *C. buccinator* (see Shufeldt, 1913, p. 151, footnote). This interpretation was entirely at variance with Cope's original description of the species, in which he said (1878, p. 388), "These tarsometatarsi indicate a species of the size of those now existing on this continent but different from them." Shufeldt (1913, p. 150), however, went so far as to discard the 3 most diagnostic of Cope's type tarsi, and practically reconstructed a new *paloregonus* based on specimens larger than any Recent bones then available, but now recognized as belonging to *C. buccinator.* Having set aside these large (*buccinator*) bones as *paloregonus,* he found it necessary to describe another species (*C. matthewi*) to account for the bones of lesser size which, in certain elements, showed structural differences from modern *C. buccinator* and *C. columbianus.*

It is evident from the present study that the tarsometatarsi selected by Cope as the type specimens of *C. paloregonus* differ from both *C. buccinator* and *C. columbianus* in characters other than size, and are, therefore, valid representatives of an extinct species. It is also evident, as before stated, that the largest of the swan bones agree, both in structural details and in size, with *Cygnus buccinator,* and should be so assigned.

Cygnus buccinator Richardson

Thirty-one specimens, representing at least 3 individuals, are assigned to the trumpeter swan, as follows: AMNH 17 (nos. 3551A, 3552), UO 6 (nos. 1663, 1664, F1678, F1679, F1680, F1683, LK222), UCLA 6 (no. 1960/17), OSC 1 (no. 2500/24), CIT 1 (no. 137/3273). All these specimens exceed the maximum available measurements of *Cygnus columbianus,* but fall within the range of *C. buccinator.* A moderate-sized distal end of ulna in the Cope collection (AMNH no. 3552), assigned by Shufeldt to *C. buccinator,* is the only fossil specimen which falls within the size range of the whistling swan. As it also agrees in size with the smaller specimens of *buccinator,* it seems undesirable to record *C. columbianus* on the basis of this one bone.

With the exception of the ulna, all the bones in the Cope collection now assigned to *buccinator* were part of the material referred by Shufeldt to the extinct *paloregonus.* Other bones, which Shufeldt identified as *C. columbianus* or *C. buccinator,* are now found to differ from the Recent species and are assigned to the extinct *paloregonus.* Among these are 3 of the original 4 tarsometatarsi on which Cope based his species.

Sthenelides paloregonus (Cope)

(Plate 1, figures 5, 6)

This extinct species of swan was described by Cope (1878, p. 388) under the genus *Cygnus.* The type material consisted of 4 tarsometatarsi (AMNH nos. 3551, 3552A, 3553). In addition to the type specimens, there are 66 other bones now assigned to this species, including tibiotarsi, carpometacarpi, humeri, scapulae, coracoids, furculae, vertebrae, and phalanges. Among these are the bones designated as types of Shufeldt's *Cygnus matthewi* and *Anser condoni,* both of which species now become synonyms of *Sthenelides paloregonus.* Detailed discussion of the elements representing the synonymized species is included in the descriptions which follow.[3]

As the specimens now assigned to *paloregonus* are studied collectively, it becomes evident that the species belongs to the group of swans (including the mute and black-necked, of the genus *Sthenelides*) in which the trachea is not looped and the furcula is simple. In addition to the simple furcula, the structural details of several other elements reflect relationship to this group. Furthermore, the bird apparently had the proportionately short tarsi and long toes characteristic of *S. olor.* In length of the skeletal elements, *paloregonus* exceeds *S. olor* throughout, and, with the exception of the shorter tarsus, overlaps the range of *Cygnus buccinator.*

In the many characters in which *S. olor* and *S. melancoriphus* do not agree, the fossil may resemble one or the other, or may be distinct from both. In other characters, all three are alike. But throughout the several elements, it is evident that the fossil is distinct from the forms now living in North America, *Cygnus buccinator* and *C. columbianus.*

Comparative measurements (in millimeters) of Sthenelides paloregonus and living species of large swans

	Sthenelides paloregonus	*S. olor*	*Cygnus buccinator*	*C. columbianus*
Length tarsus..............	*106–115	104–107	117–123	101–117
Proximal breadth tibiotarsus..	25– 27	21– 23	24– 28	21– 23
Proximal breadth humerus....	52	48– 50	48– 57	44– 53
Distal breadth humerus......	37– 38	33– 36	34– 42	30– 36
Length carpometacarpus......	139–141	125–134	121–155	128–137

*Estimated.

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[3] The 2 rami of lower mandibles later assigned by Shufeldt (1913, pl. 27, figs. 326, 327) to *Anser condoni* are discussed under "Goose, sp."

Tarsometatarsi. Cope's type material included 2 practically complete bones (AMNH no. 3552A, illustrated by Shufeldt, 1913, pl. 37, figs. 435, 436), 1 lacking the distal end (AMNH no. 3553, illustrated *ibid.*, fig. 438), and 1 with both ends missing (AMNH no. 3551). A proximal fragment (UO no. 1678) is now also available.

It is difficult to select, from the 4 types, 1 specimen which shows all the pertinent characters. Certainly the one bone (AMNH no. 3551) which Shufeldt conceded might belong to the extinct species is the least diagnostic of any. Probably the complete specimen of the left side shows the greatest number of important features, although the incomplete left is less chipped proximally and shows the hypotarsus more clearly. As it is always desirable to base an extinct species on a single type bone whenever possible, it is suggested that the complete left (AMNH no. 3552A) be so designated.

Comparative measurements (in millimeters) of tarsometatarsi

Species	Length	Breadth shaft	Breadth distal end
Sthenelides paloregonus:			
AMNH no. 3552A (left), type.....	114.6	10.9	24.8
AMNH no. 3552A (right)..........	113.7	10.2	23.8
Cygnus buccinator:			
Minimum, USNM no. 19331.......	117.8	10.3	25.9
Maximum, USNM no. 8033........	122.5	9.8	26.0
C. columbianus:			
Maximum, USNM no. 345467......	116.5	9.3	24.6
S. olor:			
Maximum, L.A. Co. Mus. no Bi918..	106.9	10.1	24.3
S. melancoriphus:			
Maximum, USNM no. 34528.......	93.8	6.3	17.2

Both complete tarsi equal medium-sized specimens of *C. columbianus* in length, but are slightly heavier in the shaft. Although Cope's description of the species was largely based on a comparison with tarsometatarsi of *C. buccinator* and *C. columbianus,* a larger series of the living species indicates that many of the characters then listed are not valid. The character of the hypotarsus, however, which is described as differing from both *buccinator* and *columbianus,* appears to be reliable. With regard to this area, Cope (1878, p. 388) said, "Third [hypotarsal] crest reaching below foramen; fourth sending keel over foramen." For *buccinator* and *columbianus* he noted, "Third crest not descending below foramen; fourth not reaching foramen" (*buccinator*), "fourth reaching foramen" (*columbianus*).

Other characters of the tarsometatarsus which now become evident are: (1) In hypotarsal region, junction of second and third ridges forming narrow keel on shaft, from which point distal edge of hypotarsus slopes decidedly upward while shaft below slopes toward external side; shallow groove present on shaft below foramen; condition of this area similar to *S. melancoriphus.* (2) Anterior face of shaft below proximal end more deeply excavated than in *C. buccinator, C. columbianus,* or *S. olor;* area deeply depressed in *S. melancoriphus,* but more cut away at internal edge. (3) Outer face noticeably swollen toward proximal end, tapering smoothly into shaft about halfway down, but ending proximally in a marked indentation just below external cotyla; condition not duplicated in any modern form compared, although indentation more marked in both species of *Sthenelides* than in *Cygnus.* (4) Line bordering external side of anterior face sloping outward slightly as external face swells outward, but inset again proximally, forming a conspicuous ridge between external and anterior faces; character approached in *S. melancoriphus,* but not identical; area more broadly and smoothly rounded in *Cygnus* and *S. olor.*

Evidently, in the swans, generic distinctions are less apparent in the tarsometatarsus than in some of the other elements. Were not other parts of the skeleton available for the fossil, it would be difficult to allocate the species generically.

Tibiotarsus. Five proximal ends are available (AMNH 3, nos. 3551, 3555A; UCMP 1, no. 31798; OSC 1, no. 2500/25). Three distal ends of tibiotarsi of swan occur in the fossil material. However, although all seem to have a more prominent posterior flange of the internal trochlea than in *Cygnus,* it is unwise to pass judgment upon them in view of their fragmentary condition.

The proximal ends display the following characters which distinguish them from *Cygnus,* and tend to link them with *Sthenelides:* (1) Area immediately below head posteriorly is depressed and bordered internally by sharp, well defined ridge proceeding down from edge of articular surface. (2) Deep, groovelike depression below articular surface posterointernally, giving evidence of a well developed flexor muscle for digits of foot. This coincides with the condition found particularly well marked in *S. olor,* in which species the toes are of greater length than in either *C. buccinator* or *C. columbianus;* in these latter species, the area for attachment of the flexor muscle is inconspicuous. (3) The two best-preserved fossil specimens appear to be broader and more flattened anteriorly below the cnemial crest than in *Cygnus;* in this respect they most closely approximate one of the available specimens of *S. melancoriphus.* As there is some variability in this character in the living forms, however, it may be of little value.

Furcula. The fragments figured by Shufeldt (1892, pl. 16, figs. 19, 26, 27; AMNH no. 3536) as the type of *Anser condoni* clearly belong to a swan of the *Sthenelides* type, and are now assigned to *S. paloregonus.* As before stated, Shufeldt presumably was not acquainted with the variation in this element in the swans. The goose furcula, though roughly similar to that of *Sthenelides,* lacks the depression and pneumaticity of the outer surface of the blades, and the broad, smooth area of the symphysis.

The blunt contour of the tip of the blade, with slight dorsal excrescence, has an almost exact counterpart in a furcula of *S. olor* now available (L. A. Co. Mus. no. B169), and in the symphyseal area closely resembles another specimen of the same species (L. A. Co. Mus. no. B11096). Both modern furculae, however, are smaller than the fossil. Each of the elements of the fossil swan has been found to run slightly larger than in *S. olor,* so that the size of the furcula is in keeping with that of the other bones assigned to *S. paloregonus.*

Examination of casts of these fragments assigned to *Anser condoni* indicates an error in the proposed restoration of the specimen. The symphysis should be set nearer the upper blade of the bone, making the over-all depth of the specimen about ¾ inch less than as shown (Shufeldt, *loc. cit.*).

Three additional fragments of furcula assigned to *A. condoni* also show resemblance to *S. olor* and undoubtedly belong to *paloregonus.* It is interesting to note that one of these specimens exactly fits the fractured end of another furcular fragment which Shufeldt himself had identified as *paloregonus.*

Coracoid. Three proximal ends (AMNH 2, no. 3551; UCLA 1, no. 1960/16). The most complete specimen is a large, stout bone with short procoracoid, and area of coracoidal fenestra indicated by a roughened internal margin. These characters relate it to *S. olor;* the procoracoid is short in *S. melancoriphus,* also, but the area of the fenestra is not clearly defined. In *Cygnus* the procoracoid is longer and there is no indication of a fenestra, except, in some specimens, a minute perforation.

Scapular facet broad and shallow, resembling *Cygnus* in depth, but more evenly rounded, as in *Sthenelides.* Furcular facet flattened against shaft anteriorly with only slight undercut near brachial tuberosity, as in *Sthenelides;* in *Cygnus,* facet undercut for its full extent. Shaft beneath brachial tuberosity only slightly depressed, being closer to *S. olor* than to *S. melancoriphus.* Neck and coracohumeral surface more concave than in *Cygnus* or *S. olor;* resembling *S. melancoriphus.*

Scapula. There are 5 proximal ends of swan scapulae in the several collections from Fossil Lake (AMNH 3, nos. 3551, 3554; UCMP 1, no. 31769; UO 1, no. F1672). Two of these (AMNH no. 3554 and UO no. F1672) were assigned by Shufeldt to his *Cygnus matthewi.* The others were all assigned to *paloregonus.*

Study of this element in living species of swans reveals a marked variability in structural details. In general, however, *Sthenelides* shows a longer, more slender acromion and a relatively thicker shaft than does *Cygnus.* In *Cygnus* the muscle attachment on the ventral surface of the acromion forms a short crest slightly back from the internal border proximally, but curving toward this border distally. In *Sthenelides* the attachment follows the internal edge of the bone more closely. In *S. olor* there is no marked crest, though there may be a short depression on the ventral surface of the acromion. In *S. melancoriphus,* however, there is a long line which, at its distal extremity, curves toward the middle of the bone (the opposite direction from that found in *Cygnus*).

On the basis of the characters given above, the bone figured by Shufeldt (1913, pl. 26, fig. 310; AMNH no. 3551A) as *paloregonus* belongs with *Cygnus buccinator.* The exaggerated curvature may possibly be due to injury to the bone early in life, although it could be attributed to individual variation; there is a tendency to greater curvature in *Cygnus* than in *Sthenelides.* Two other specimens (UCMP no. 31769 and AMNH no. 3554) are closer to *Sthenelides,* although the acromion is not quite as extended as in *S. olor* or *S. melancoriphus.* These specimens undoubtedly represent the extinct *S. paloregonus.* It is impossible definitely to assign the University of Oregon specimen or the remaining Cope scapula. The surface is weathered in both bones, and the contours are worn.

Humerus. The best specimens of this element are in the UCLA collection (no. 1960/16), where one proximal and one distal end appear to be parts of the same bone; there is an additional distal end, as well. Of the 6 fragments in the Cope collection which Shufeldt assigned to *paloregonus,* 3 are undoubtedly *buccinator,* and a smaller proximal end is *Branta,* leaving only 2 fragments of distal end which may be assigned to the extinct species (AMNH no. 3551). The shaft of large humerus in the Condon collection (UO no. 1663), which was previously allocated to *paloregonus,* falls into *C. buccinator* upon more careful scrutiny.

The humeri now assigned to *S. paloregonus* are large, exceeding *S. olor* and *C. columbianus* in size but not equal to the maximum of *C. buccinator.* Except in size, these fossil specimens closely resemble *S. olor.* Proximal end: (1) Intermuscular line, on crest of anterior face, short and indefinite, and not turning inward below head; in *Cygnus* the line runs along the crest and turns inward about ¼ inch below head. (2) Area immediately adjacent to median crest deeply depressed and perforated with numerous pneumatic foramina. This condition is more marked in the fossil than in any of the living forms examined, although there is a tendency to depression and very slight perforation in *S. olor* and *C. buccinator*. (3) Attachment of supraspinatus muscle clear-cut in outline and situated below pneumatic foramen, bordered by a raised line continuous with median crest, as in *S. olor*. This attachment is less clearly marked in *Cygnus* and in *S. melancoriphus,* spreading past the median crest and lacking the raised bordering line at the edge. (4) External tubercle projecting outward more than in *Cygnus.* (5) Ligamental furrow, on palmar face, broad and less deeply cut than in *Cygnus* or *S. melancoriphus,* being closer to *S. olor,* but angular at the tip. (6) Palmar area between head and internal tubercle marked by depressed triangular area, lacking in *Cygnus;* line of demarcation of depression less evident in *Sthenelides* than in fossil, but condition closer in this genus than in *Cygnus.*

Distal end: (1) Attachment of anterior articular ligament short and broad, and heavily bordered on its outer edge next to attachment of pronator brevis muscle. Size of attachment similar in *Sthenelides,* but outer edge, though clear-cut, lacks heavy border. Area long and narrow and smoothly rounded at edges in *Cygnus.* (2) Impression of brachialis anticus relatively long, narrow, and, in comparison with *Cygnus,* less clearly outlined; most closely approximating impression as seen in *S. olor,* though in neither species of *Sthenelides* is area as clear as in *Cygnus.* In the latter genus, impression short and broad (particularly at its proximoexternal edge), clearly outlined, and usually deeply depressed.

Carpometacarpus. Two complete specimens (AMNH no. 3554 and UO no. F1681, described by Shufeldt as *C. matthewi*), and 2 proximal ends (UO nos. F1677 and F1683 right).

In size, these specimens exceed *C. columbianus* and *S. olor* and fall within the range of *C. buccinator.* The principal distinguishing characters concern the area of the pisiform process and the height of the trochlear crests. The shape of the process of metacarpal 1 does not seem to be wholly dependable, although there is a tendency in the fossil, as in *Sthenelides,* to be straighter and more evenly swelled at the tip, as seen in anterior view; in *Cygnus* the process inclines more definitely toward the internal side.

Characters of particular diagnostic value: (1) Area below pisiform process excavated into a distinct pitlike depression, the posterior rim of which is marked; in *Cygnus* this area roughened, sometimes depressed, but tending to slope away toward posterior face without an intervening rim. Fossil similar to *S. olor,* though depression more proximal in extent than in living form and pisiform process itself broader and less pointed; *S. melancoriphus* lacks depression. (2) Distance from pisiform process to tip of internal edge of trochlea relatively less than in *Cygnus* or *S. olor,* and similar to *S. melancoriphus.* (3) External crest of trochlea short, and lobe at its distal edge appears aborted in comparison with *Cygnus;* length of crest similar to both living species of *Sthenelides,* but shape of lobe peculiar to fossil specimens.

The 2 carpometacarpi described as *C. matthewi* agree with the other 2 available specimens (of proximal end), now assigned to *paloregonus,* in all characters described, and no other carpometacarpi distinct from the living species are present in the collections. The indications of relationship to *Sthenelides* coincide with the condition found in the other elements referred to *S. paloregonus.* It is evident, therefore, that *C. matthewi* must become a synonym of *S. paloregonus.*

A fragment of distal end of carpometacarpus (USNM no. 7593) was also assigned to *matthewi* by Shufeldt. This specimen is too fragmentary to justify identification beyond the fact that it is swan.

Comparative measurements of carpometacarpi

Species	*a* Greatest length (mm.)	*b* Depth proximal end (mm.)	*c* Height external crest (mm.)	*d* Distance pisiform process to proximal tip internal crest (mm.)	Ratios (%)	
					c to *b*	*d* to *b*
Sthenelides paloregonus.........	139–141	32.3–34.8	20.0–21.4	10.0–10.8	59.8–61.8	30.0–31.3
S. olor...........	125–134	29.1–30.5	18.1–18.2	10.0–10.7	59.7–62.3	34.4–35.1
S. melancoriphus.	103	24.1	14.3	7.5	59.4	30.1
Cygnus buccinator	121–156	29.7–36.1	19.2–23.0	11.0–11.8	63.7–64.7	33.7–37.1
C. columbianus...	128–137	26.7–29.6	18.8–19.7	10.3	65.6–70.5	37.4

Vertebrae. A cervical vertebra in the collection of the U. S. National Museum (USNM no. 7589) was assigned by Shufeldt to *Anser condoni.* On inspection, however, it is found to be not goose, but swan. Although there are many similarities between the vertebrae of geese and of swans, those of the latter are relatively longer and straighter and more compact. The cervical vertebra of the goose narrows more in the center and flares at the ends. Furthermore, the foramina posterior to the processes are even more marked in geese than in swans, whereas no. 7589 has none, resembling in this respect specimens of *S. olor.* In *Cygnus,* small foramina are present. There are a number of other cervical vertebrae in the several collections which are similar to the U. S. National Museum specimen in the absence of foramina, and are thought to belong to *S. paloregonus.*

Phalanges. Two complete and two incomplete pedal phalanges, representing the first segment of the second and fourth digits, are available in the material now assigned to the extinct swan. They show the relatively long, straight shaft characteristic of *Sthenelides.* In *Cygnus* these elements deepen markedly at the proximal end and taper toward the middle, presenting a distinctly curved contour.

Geese

There are nearly 400 bones of geese in the combined collections from Fossil Lake. At least two-thirds of these were examined by Shufeldt, and formed the basis of his recognizing the following species: *Branta canadensis, Branta bernicla, Branta hypsibata, Branta propinqua, Chen hyperborea, Chen caerulescens, Anser albifrons,* and *Anser condoni.* The writer is not in complete agreement with Shufeldt's identification of many of the elements. In the approximately 220 bones which can be generically identified, however, some of the same living species are found to be represented, and the validity of at least one of the extinct types is established. Another extinct form is added.

Branta canadensis (Linnaeus)

Among the living species, *Branta canadensis* is well represented in the fossil deposit, and includes extremes in size corresponding to both *Branta canadensis canadensis* and *B. c. minima.* There is not a continuous series from large to small, however. As Shufeldt indicated, there are some specimens which appear too small to be *B. c. canadensis,* but since, with the possible exception of 2 fragments, they are larger than any available specimens of *B. c. leucopareia,* it seems wiser not to give them a racial assignment.

In the combined collections, there are 97 bones of large *Branta canadensis,* representing 9 or 10 individuals, and 15 (3 individuals) of small size, presumably *B. c. minima.*

Branta bernicla Linnaeus

Six specimens (2 individuals), resembling black brant, indicate the presence of the species *Branta bernicla* (AMNH 4, OSC 1, and UCMP 1). Of the 5 coracoids so assigned by Shufeldt, 4 are here discussed under two other species (*Branta propinqua* and *Anabernicula* sp.). The remaining coracoid is a fragmentary specimen, apparently brant.

Anser albifrons (Scopoli)

Sixteen bones (5 individuals) are assigned to *Anser albifrons.* This species and *Chen hyperborea* are so similar in structural characters and size that it is almost impossible to distinguish them in certain elements, or from fragmentary material. Specimens of both species are undoubtedly included in the 150 goose bones of medium size which cannot be generically assigned.

Chen hyperborea (Pallas) and **Chen rossii** (Cassin)

The snow goose and the Ross goose are both represented, the former by 28 specimens and 5 individuals, the latter by 7 specimens and 3 individuals. Shufeldt's record of *Chen caerulescens* was based on 2 scapulae. The scapula is an element of variable character which is rarely dependable. It is doubtful whether these bones should receive even generic classification, and no justification is apparent for recording them as blue goose.

Goose, species (large)

(Plate 2, figure 3)

There are, in the several collections from Fossil Lake, a few goose bones of particularly heavy proportions and large over-all size. These include 2 tarsometatarsi, a coracoid, a humerus, and 2 fragments of lower mandibles.

One of the tarsi (AMNH no. 3542A) is that figured in two sections by Shufeldt (1913, pl. 28, figs. 340, 343) and assigned to *Branta canadensis.* The other (AMNH no. 3543A) was erroneously figured as the type of *Branta hypsibata* (*ibid.,* pl. 27, fig. 320), a species which Cope described as being particularly slender of build. Both bones are massive toward the proximal end, tapering in toward the middle of the shaft. Possibly they are assignable to *Branta canadensis,* but none of the specimens of Canada goose at hand is as heavy.

The coracoid (OSC no. 2500/44) is a dorsal part only. The bone is heavier even than in *Branta canadensis canadensis,* and lacks the deep excavation beneath an overhanging furcular facet which characterizes members of the genus *Branta.* The condition in the fossil more closely resembles that in *Anser* or *Chen,* but the bone is relatively thicker, as well as actually larger than any specimen of either of these genera at hand.

The 2 mandibles (AMNH no. 3535B) were referred by Shufeldt (1913, pl. 27, figs. 326, 327) to *Anser condoni.*[4] They are similar to *Chen* in their short, stocky build, but are straighter and somewhat heavier than available specimens of *Chen hyperborea hyperborea.* In both *Anser* and *Branta* (even including *B. c. canadensis*) the mandible is more slender. The approach of these mandibles to the size of *Chen hyperborea* precludes any possibility of their belonging to the same bird from which the furcula described as *Anser condoni* was taken. The latter specimen, as pointed out under *Sthenelides paloregonus,* is large even in comparison with the swan.

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[4] A third ramus bearing this number (AMNH 3535A, figured by Shufeldt, *op. cit.,* pl. 27, fig. 324) agrees with *Chen hyperborea* and is so assigned.

The humerus is a distal half (CIT no. 137/3280). Although the distal part of this element is difficult to assign, there is a tendency to greater development of the impression of the brachialis anticus muscle in *Chen* than in the other genera—either in deeper excavation or in greater extent of the depression. The fossil bone has a very deeply excavated impression. The bone shows the same sturdy proportions which characterize the other elements discussed, and is slightly larger than any available specimen of *Branta c. canadensis.*

No attempt is made here to assign these sturdy goose bones definitely. The bones are too few and too fragmentary to risk erection of a new species in a group as variable as the geese. Possibly they do not all belong to the same species, but may include aberrant individuals of more than one form.

Branta hypsibata Cope ?

(Plate 2, figure 4)

Cope's description (1878, p. 387) of this species is based on a single tarsometatarsus. This bone, he said (*ibid.*), is "longer and more slender than that of the *A. canadensis.*"[5] Unfortunately, Cope did not figure or number the type specimen. Consequently we cannot now be certain of its identity. It is evident that Shufeldt (1913, pl. 27, fig. 320) was in error in believing the tarsus which he figured to be Cope's type. He gives the length of the bone as 90 mm. and describes it as stouter than *Branta canadensis.* The latter statement is exactly opposed to Cope's own description, and the length is 3 mm. too great. A comparison of quotations from the two authors, and description of the specimens concerned, follows:

Cope, 1878, p. 387	*Shufeldt, 1913, pp. 147–148*
"*Anser hypsibatus,* sp. nov."	". . . Cope described the extinct goose, *Branta hypsibata,* written by him *Branta hypsibatus.*
"A single tarso-metatarsus, perfect except in the hypotarsus, represents this goose."	"The reference was made upon a single bone, a right *tarso-metatarsus,* and this bone is shown in Fig. 320 of plate XXVII of the present paper. It is imperfect, to the extent of having the hypotarsus almost entirely broken off, as well as the posterior parts of the distal trochleae.
"The element mentioned is longer and more slender than that of the *A. canadensis,* and differs in a variety of points from that bird."	"This now long-extinct species was apparently about the size of *Branta canadensis;* but the bones of the skeleton were stouter and of different proportions."

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[5] The tarsal measurements of *Branta canadensis canadensis,* now available, far exceed the measurement of length given for *hypsibata* (87 mm.).

Cope, 1878, p. 387			*Description of bone selected by Shufeldt as "type"*
"Length of bone		0.087M	89 mm. (90 mm. according to Shufeldt)
Transverse diameter	proximally	0.016	19.4
	medially	0.006	8.2
	distally	0.018	19.5
Width of internal cotylus		0.007"	8.3
". . . proximal two-fifths of the shaft is more deeply grooved [compared with *B. canadensis*],			Moderately depressed.
"and the lateral ridges are more prominent. This is especially true of the external angle, which continues straight to the anterior border of the diaphysis, where it is wanting or weak in the *A. canadensis.*			Lateral contours of bone smoothly rounded. External angle veers off toward outside proximally and is not continuous to the anterior border of the diaphysis.
"The external side is also plane, or nearly so, to this angle, while in the existing bird it is swollen having a narrow convex surface, which passes insensibly into the anterior and posterior faces.			External side swollen proximally below the articular end, having a narrow, convex surface such as Cope described for *B. canadensis.*
". . . the posterior face of the shaft at its middle is oblique, sloping forward and inward. In *A. canadensis* it is plane or gently convex. The superior part of the posterior face is oblique in the opposite direction and is much narrower than the corresponding face in *A. canadensis.*"			Posterior face of shaft at middle, convex. Superior part slopes markedly toward external side, and is very broad.

The matter of determining the original, correct type presents certain difficulties. Cope indicated (1878, p. 388) that the bone was found by Thomas Condon. There is, however, no complete goose tarsus which fits the description in the Condon collection as it now stands. In the Cope collection there are 3 complete tarsi over 85 mm. in length. All agree in being nearly perfect except in the hypotarsus, as described for the type of *hypsibata*. One (AMNH no. 3542A) was in two sections when figured by Shufeldt (1913, pl. 28, figs. 340, 343). It is too long (93 mm.) and too sturdy to be the type of *hypsibata*. The tarsus figured adjacent to the specimen supposed by Shufeldt to be the type fits the description better, but, on careful examination of the specimen, the measurements and structural characters are found not to agree with Cope's statements. The third bone (AMNH no. 3539B), which Shufeldt figured as *Anser albifrons gambeli* (1913, pl. 24, fig. 295), closely accords with Cope's description of *hypsibata* and certainly bears no resemblance to any specimen of *Anser albifrons* available here. In referring to this specimen and others figured with it, Shufeldt (*ibid.*, p. 146) said, "and with respect to *Anser a. gambeli,* the bones here used were Cope's types." Although the statement is not clear in its reference to bones of Recent species as "types," it at least indicates that Cope had examined the specimens, and raises the possibility that he had studied several bones at once and neglected to separate his extinct form from the others.

The measurements of this long, slender tarsus agree within a few tenths of a millimeter with those which Cope gave for *hypsibata*. In structural details the bone coincides with the characters pointed out by Cope, particularly in the flatness of the external side and the prominence of the lateral ridges of the anterior face. The anterior face is well grooved, down nearly to the mid-point of the shaft. Although specimens of *Branta canadensis* vary in depth of anterior grooving, many are less deeply grooved than the fossil, and in nearly all, the groove is less distal in extent. Posteriorly, the raised border of the external surface produces an effect of a slight inward slope at the middle of the shaft; more proximally, the bone slants toward the external side and the area between the end of the internal calcaneal ridge and the posterior border of the external side is narrow. In view of these many features which correspond to Cope's description, it is the present writer's belief that this tarsus is the type of *B. hypsibata*.[6]

It is a question, however, whether the specimen just described actually represents an extinct species, in other words, whether *B. hypsibata* is a valid species. In certain respects the bone closely resembles available specimens of *Chen hyperborea:* (1) general over-all slenderness; (2) extent and depth of anterior grooving; (3) raised posterior border of external side of shaft and tendency to slope inward; (4) narrow posterior surface just below hypotarsus. Even the length is within the range of specimens of *C. hyperborea* now at hand. There is no available specimen of *Chen,* however, in which the external face below the proximal end is flattened as in the fossil, or in which the external ridge is as prominent in this region. As these latter characters tend to vary widely throughout the geese, they are not wholly reliable. There is, for example, a Recent specimen of *B. c. canadensis* in the Los Angeles County Museum collections which has a marked external ridge up to the articular end, and a flattened external surface, whereas the majority of bones of *canadensis* are as Cope described them in his comparison with *B. hypsibata.* The characters of the posterior surface seem to be more reliable, and in these the fossil is similar to *Chen.*

In consideration of the above facts, it is strongly suggested that the tarsometatarsus upon which Cope erected *Branta hypsibata* is in reality *Chen hyperborea.*

A number of other elements were referred to *Branta hypsibata* by Shufeldt (AMNH no. 3543, USNM no. 3570). As these were all selected on the basis of the heavy tarsometatarsus thought by Shufeldt to be the type of *hypsibata,* they can hardly be expected to accord with the dimensions or characters of the slender-legged bird which Cope described. One of these, a distal end of tarsometatarsus (USNM no. 3570, figured by Shufeldt, 1913, pl. 9, fig. 5), is unmistakably flamingo.

Apart from the "types" of *Anser condoni* and *Branta hypsibata,* species whose validity is now questioned, there are 47 specimens in the assemblage which are assignable to extinct species of geese. These are divided between the species *Branta propinqua* and an added species of even smaller size, which is here assigned to Ross's genus *Anabernicula,* originally described from the McKittrick Pleistocene asphalt deposits.

Branta propinqua Shufeldt

Twenty bones, representing 5 individuals, are now thought to belong to this extinct goose. The type is a humerus (AMNH no. 3547, Shufeldt, 1913, pl. 29, fig. 350), 11 mm. shorter than the smallest available specimen of *Branta bernicla nigricans.*

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[6] The fact that the bone is now found with the Cope material rather than in the Condon collection is of little consequence, as there is other evidence of the two collections' having been mixed.

From Shufeldt's description (1892, p. 407), it appears that it was on size alone that the species was separated from the black brant. An excellent cast of the type is at hand for study. The specimen is distinguished from available humeri of Recent *B. b. nigricans* by more medially extending pneumatic foramen, higher apex of shaft on anconal side proximally, and more marked depression below head. In general it may be said that *B. propinqua* tends to deviate from *nigricans* in a manner somewhat similar to that shown by *B. c. minima.* The pneumatic foramen, however, is less medial in position in the fossil than in the cackling goose, and the shaft tends to be more deeply excavated adjacent thereto, accentuating the high apex.

Among the specimens referred to *propinqua* by Shufeldt is a proximal end of humerus slightly larger than the type, but with similar characters. Two other proximal ends of humerus (AMNH no. 3538C and UCMP no. 31768) are probably also of this species, although the University of California specimen overlaps the range of *nigricans* in breadth of proximal end.

Other elements in the combined collections which are believed to be assignable to *B. propinqua* are: 2 carpometacarpi (one, AMNH no. 3548A, referred to *B. c. minima;* the other, AMNH 3705, previously unidentified), 6 tarsometatarsi (AMNH 5, no. 3496A, assigned to *Larus robustus;* UCLA 1, no. 1960/14), and 3 coracoids (AMNH no. 3545A, identified previously as *B. bernicla*). An ulna, scapula, furcula, and fragment of coracoid (OSC no. 2500/47) are tentatively so referred.

The carpometacarpi are 2 mm. smaller than the smallest available specimen of *nigricans,* and the process of metacarpal 1 is lower. The tarsometatarsi and coracoids overlap *nigricans* in length but are distinguished from that species as follows: Shaft of tarsus broader transversely than deep anteroposteriorly (reverse is true of *nigricans*); coracoid showing marked depression on anterior side near sternal end between sternal facet and intermuscular line; continuation of procoracoid to shaft slightly notched in region of coracoidal foramen. As in the case of the humerus, the characters which distinguish these elements from *nigricans* tend toward *minima,* without being exactly similar. In the coracoid, both characters are more marked than in *minima,* and in the tarsometatarsus the transverse breadth of shaft is relatively greater.

Comparative measurements of Branta propinqua and Recent brants

	Branta propinqua	*B. bernicla nigricans*	*B. canadensis minima*
Coracoid, length (mm.)	41.4– 46.0	44.7– 49.9	48.8– 53.0
Tarsometatarsus:			
Length (mm.)	56.4– 59.3	58.0– 65.1	66.0– 75.7
Ratio, breadth to depth of shaft (%)	100 –111	82 – 95	104 –106
Ratio, breadth of shaft to length of bone (%)	7.9– 8.4	6.3– 7.5	6.7– 8.0
Carpometacarpus:			
Length (mm.)	60.1	62.9– 70.4	70.8– 78.0
Ratio, height of process of metacarpal 1 to depth of same (%)	55 – 60	64 – 67.5	59 – 62.5
Humerus:			
Length (mm.)	106.2*	117.5–128.3	125.7–137.0
Breadth of proximal end (mm.)	21.3– 24.1	23.3– 26.2	24.6– 27.6

*Measurement as given by Shufeldt was 107 mm.

A number of other elements were referred to *B. propinqua* by Shufeldt, and many of them were figured (1913, pl. 29). These are now assigned to other species of geese or ducks.

Anabernicula, species

In addition to the type of *Branta propinqua,* Shufeldt (1913, pl. 38, fig. 465) figured another, still smaller humerus (AMNH no. 3548C) which he assigned (along with the femur in fig. 464) to *Branta c. minima.* The allocation of the femur need not be questioned. There is a sharp distinction, however, between the little fossil humerus and this element in the cackling goose. Not only is the fossil 27 mm. smaller than the smallest available humerus of *minima,* but the short deltoid crest and the relatively low external tuberosity are ducklike in character. The bone shows a striking resemblance to the extinct "pigmy goose," *Anabernicula minuscula* (Wetmore).

The type of *A. minuscula,* described under the genus *Branta* (Wetmore, 1924, pp. 6–7), was found in the Upper Pliocene of Arizona. Later, after studying a series of small goose tarsometatarsi in the McKittrick Pleistocene, Ross (1935) described *Anabernicula gracilenta.* Subsequent examination of the humeri associated with Ross's *A. gracilenta* in both the McKittrick and Rancho La Brea deposits led to the belief that the bird represented was Wetmore's *minuscula.* It was clear, however, from the tarsometatarsi that the species should appear under the new generic name *Anabernicula. Anabernicula gracilenta* was therefore listed as synonymous with *minuscula,* and the latter was recorded from the two California localities (Howard, 1936, p. 35).

In addition to the figured humerus in the Fossil Lake material, now assigned to *Anabernicula,* a number of other specimens are found to agree closely with corresponding elements of the pigmy goose in the Los Angeles County Museum collection from Rancho La Brea. The complete list follows: 9 humeri (AMNH, 8, nos. 3521H, 3546D, 3548C, previously referred to *Glaucionetta islandica, Branta propinqua,* and *B. c. minima,* respectively; UCLA, 1, no. 1960/13). 3 carpometacarpi and 3 ulnae (AMNH, 2 carpometacarpi, 3 ulnae, no. 3546D; UO, 1 carpometacarpus, no. F1670; all previously assigned to *B. propinqua*). 1 femur (AMNH no. 3500, figured by Shufeldt, 1913, pl. 31, fig. 398, as *Mergus,* sp.). 2 coracoids (AMNH nos. 3510, 3518, identified as ducks). 6 fragments humeri, parts of carpometacarpus, femur, tarsometatarsus, and scapula (AMNH no. 3677); 2 coracoids (UCLA no. 1960/12, CIT no. 137/3279); and 2 ulnae (UCMP no. 31794), all previously unidentified. These 32 specimens represent at least 7 individuals.

The inclusion here of several bones which Shufeldt had referred to *B. propinqua* raises the question of possible identity of the two species. The type humerus of *propinqua,* however, not only is of greater over-all length than the maximum humerus of *Anabernicula,* but shows characters of deltoid crest and external tuberosity that are distinctly gooselike, rather than ducklike as in *Anabernicula.*

In the series of humeri, considerable size variation is noted, the smallest complete humerus measuring 85 mm., the largest 98 mm. As no marked structural differences are apparent between the maximum and minimum specimens, it is presumed that only one species is represented. Comparing the series with a cast of the type of *A. minuscula,* and with the humeri in the Los Angeles County Museum collection from Rancho La Brea, the resemblance is found to be very close as far as the proximal end is concerned. The characters enumerated for the type of *minuscula* are present, the outstanding ones being as follows: (1) Humeral head forming a right angle in region of capital groove; (2) acute ridge extending to base of humeral head on anconal surface; (3) external tuberosity reduced; (4) excavation between external tuberosity and humeral head slight; (5) shaft depressed anconally below humeral head, delimited proximally by a line continuous with ridge on shaft; (6) bicipital crest rounded in contour and forming clean-cut angle in junction with shaft. There appears to be a more marked anconal bend of the proximal end toward the internal side in the Oregon specimens than in the Rancho La Brea humeri, a condition suggestive of that found in the mergansers, though less pronounced. The cast of the type of *minuscula* does not seem to be quite reliable in its general contours, judging from the illustration (Wetmore, 1924, fig. 3). The bone had been badly splintered and it is likely that the restored section could not be accurately cast. The cast indicates a straighter bone than those from either Oregon or California, with a flexure of anconal end no greater than in the latter.

The distal end of the humerus is lacking in the Arizona type. Comparison of the Oregon and California specimens shows a difference in the area of the attachment of the anterior articular ligament. In the Oregon bones the ligamental attachment is rounded in lateral profile, with the more lateral attachment of the pronator brevis almost merging into it. This character is gooselike as distinguished from the more ducklike condition found in the Rancho La Brea bones, which have a pointed and projecting ligamental attachment, clearly separated from muscle scar. Although there is great variability in some of the structural details of the Rancho La Brea series, this character of distal end is similar throughout. It would seem, therefore, that this is an important diagnostic feature, on the basis of which the California and Oregon bones should be specifically (at least) separated.

The occurrence of this distinction in the distal ends of the humeri from the two localities, when the proximal ends are so similar, raises the question as to which, if either, of the west-coast forms can now be associated with *minuscula.* In acuteness of the ridge on the shaft, the Oregon bones seem somewhat closer to the Arizona type, but if the flexure of the anconal end is accurately portrayed in the cast, the straightness of the type of *minuscula* is more closely approximated in the California humeri. A careful comparison of all west-coast specimens with the type itself will be necessary before a definite assertion can be made.

An incomplete coracoid in the material from Arizona (USNM no. 10555) was mentioned by Wetmore (1924, p. 7) as possibly anserine in affinity. This specimen is now at hand and seems unquestionably to belong to the same species represented by the type humerus of *minuscula.* It agrees with the series of pigmy goose coracoids from Rancho La Brea in the following particulars: (1) Closer to ducks than geese in general proportions, but somewhat stouter; (2) anterointernal edge of shaft rounded and thickened as in the geese; (3) head more rounded and heavy than in ducks. The four coracoids in the Fossil Lake material also reflect these characters. This element does not display any features upon which the birds from the three localities may be set apart.

The entire subject of the "pigmy geese" merits detailed study, not only to ascertain the species represented, but to establish the relationships of the genus itself. Recent comparisons with the shelldrakes show marked resemblances there, as well as with the tree ducks. Until the subject can be given the time it deserves, however, it seems preferable to designate the Oregon specimens as *Anabernicula,* species. The presence of bones of the same peculiar type in three widely separated areas, and well represented in the deposits of California and Oregon, suggests the possibility of the common occurrence in prehistory of a now extinct anseriform subfamily.

List of Geese

Species	No. bones	No. individuals
Branta canadensis canadensis	97	10
Branta canadensis minima	15	3
Branta bernicla	6	2
Branta propinqua	20	5
Anser albifrons	16	5
Chen hyperborea	28	5
Chen rossii	7	3
Anabernicula, species	32	7
Branta hypsibata?	1	1
Goose, species (large)	6	2
Unidentifiable goose bones	158	2
	386	45

Ducks

As would be expected, the Fossil Lake deposits contained abundant remains of ducks. The combined collections include 571 duck bones, representing from 86 to 106 individual birds. According to Shufeldt's listing, 22 species of these waterfowl were included. The number has been lessened to 15, however, as a result of this study.

The ducks form an extremely variable group, in which there is great overlapping of specific, or even generic, characters. Without a large series of Recent skeletons for comparison, it is almost impossible to identify many of the species. It is not surprising, therefore, to find many misidentifications in the material examined by Shufeldt. In fact, so large a number of errors appears that it is useless to attempt to clarify each one here. The discussion which follows represents a complete resurvey of the subject, and, though many of the same species are now listed, the individual specimens are largely reassigned.

A statement as to the abundance of the various kinds of ducks is necessarily more generalized than in those groups in which distinction between species can be recognized in all elements. The surface-feeding ducks are unquestionably predominant, however, and the baldpate is probably the most numerous. Actually, more specimens of the diving ruddy duck have been definitely recognized, but as this species is easily distinguished throughout its skeleton, the specimens so assigned include a greater variety of elements than in the case of the baldpate. In number of individuals represented, the ruddy falls second to the baldpate. The green-winged teal and shoveller are fairly numerous, the pintail and mallard less so.

Of the diving ducks, aside from the ruddy and redhead, no species is represented by more than 3 individuals. The total number of bones of divers is 148 (34 to 38 individuals), of surface feeders 226 (41 to 53 individuals). About 200 specimens cannot be determined in detail and are listed only as "duck, species." These include another 11 to 16 individuals. Generally speaking, the identified species are those which are to be found today around similarly situated lakes of Oregon.

Anas platyrhynchos Linnaeus

The mallard was present in the Pleistocene lake in small numbers. Fifteen bones are definitely so assigned, indicating at least 4 individuals. An ulna, humerus, and carpometacarpus are included here which, though shorter than any Recent bones available for comparison, have the heavy proportions of *Anas platyrhynchos* as contrasted with *A. acuta*. Each of these three is approximately 3 mm. shorter than the smallest Recent mallard bone in our collections.

Anas acuta Linnaeus

The pintail, like the mallard, was only fairly abundant. Eleven bones, representing 4 individuals, may be definitely so assigned. Another 31 specimens resemble both *Anas acuta* and *Mareca americana,* and cannot be definitely placed with either form.

Anas carolinensis Gmelin and **Anas cyanoptera** Vieillot

The teals were well represented in the deposit, with 47 bones, indicating at least 9 individuals.

Anas carolinensis was most abundant, with 20 bones, indicating 5 individuals, definitely identified. Another 3 bones of 2 birds are assigned to *A. cyanoptera.* The other specimens cannot be specifically determined.

Mareca americana (Gmelin)

The baldpate was probably the most abundant of all the ducks at Fossil Lake. At least 35 specimens, indicating 15 birds, are definitely recognizable. In addition there are 45 other specimens, overlapping *Anas* on the one hand and *Spatula* on the other, some of which undoubtedly belong with *Mareca.*

Spatula clypeata (Linnaeus)

Twenty-eight bones of the shoveller occur in the combined collections and represent at least 7 individuals. Another 14 bones resemble both *Spatula* and *Mareca,* and probably include both genera.

Nyroca americana (Eyton)

The redhead is the best represented of the nyrocine ducks. Seventeen bones, indicating at least 8 individuals, are unquestionably of this species. No evidence of the canvasback was found; the bones on which Shufeldt based his record of the species proved to be pintail.

Nyroca collaris (Donovan) ?

Two bones (coracoid, AMNH no. 3527E; humerus, UO no. LK226), of the same size as those of the lesser scaup, resemble the ring-necked duck more closely in details of structure. As these structural characters are similar in bones of the larger *Nyroca americana* as well, there is a possibility that the two specimens represent a small redhead rather than *N. collaris.*

Nyroca affinis (Eyton)

Of less abundance than the redhead is the lesser scaup. Seven bones are so assigned, but only 2 individuals are with certainty represented. Both scaups are reported in Oregon today, but the greater cannot be definitely identified here. All identifiable nyrocine bones of the proper size are assignable to *N. americana.*

Charitonetta albeola (Linnaeus)

The bufflehead was rare, but its presence is unquestionably attested to by 2 bones, a carpometacarpus (AMNH no. 3529A) and an incomplete humerus (UO no. F1662).

Clangula hyemalis (Linnaeus)

Although the femur and ulnae on which Shufeldt based his record of the old squaw are wrongly identified, a number of other specimens resemble this duck and are so assigned. These are: 2 humeri, a carpometacarpus, and 2 coracoids (AMNH nos. 3508B, 3517C, and 3690), a humerus, carpometacarpus, and ulna (OSC no. 2500/59), and a coracoid and humerus in the Condon material (unnumbered). They represent at least 2 individuals.

Melanitta perspicillata (Linnaeus)

Three bones in the Cope collection are indistinguishable from the surf scoter and are so assigned. All may be of the same individual. This species was not recorded by Shufeldt, the 3 bones having been assigned to three different species.

Erismatura jamaicensis (Wilson)

The ruddy duck is well represented in the several collections. A total of 57 bones indicates at least 11 individuals. This is probably the most easily recognized, osteologically, of all the ducks, a fact which undoubtedly accounts in part for the large number of specimens so assigned.

Mergus merganser Linnaeus and **Mergus serrator** Linnaeus

Both the American and red-breasted mergansers are found in the remains from Fossil Lake. Twenty-nine bones probably represent at least 7 individuals. A third species may be present, as several bones which resemble *Mergus* are smaller than any specimens of *M. serrator* at hand for comparison. They are not as small, however, as in *Lophodytes cucullatus,* nor do they correspond in characters to specimens of that species.

List of Ducks

Species	No. bones	No. individuals
Anas platyrhynchos	15	4
Anas carolinensis	20	5
Anas cyanoptera	3	2
Teals, miscellaneous	24	2
Anas acuta	11	4
Anas acuta or Mareca americana	31	0 to 6
Mareca americana	35	15
Mareca or Spatula	14	0 to 6
Spatula clypeata	28	7
Anatinae, miscellaneous	45	2
Nyroca americana	17	8
Nyroca collaris?	2	1
Nyroca affinis	7	2
Nyroca, miscellaneous	10	..
Charitonetta albeola	2	1
Clangula hyemalis	10	2
Melanitta perspicillata	3	1
Erismatura jamaicensis	57	11
Mergus merganser	3	2
Mergus serrator	19	3
Mergus merganser or serrator	7	2
Diving ducks, miscellaneous	11	1 to 4
Ducks, miscellaneous (specifically unidentifiable)	197	11 to 16
	571	86 to 106

It is impossible to corroborate the occurrence of the other species of ducks recorded by Shufeldt. The bones identified as Steller's eider (*Polysticta stelleri*) are assignable to *Nyroca, Mareca,* and *Anas.* Of those recorded as golden eye (*Glaucionetta islandica*), at least half are bones of surface-feeding ducks, and the others belong to species of *Nyroca, Melanitta,* and *Mergus,* with 1 assignable to a goose. The bones recorded as wood duck (*Aix sponsa*) are largely shoveller. Of the 3 specimens assigned to *Histrionicus histrionicus,* 1 is probably old squaw, another baldpate, and the third is too badly defaced to make a definite identification. The bones recorded as *Lophodytes cucullatus* are now found to belong to old squaw, scaup, and one of the anatines.

FALCONIFORMES

Falconiformes recorded from the Fossil Lake deposits include four eagles and one hawk, as follows: *Haliaeëtus leucocephalus, Aquila chrysaëtos, Aquila pliogryps, Aquila sodalis,* and *Circus cyaneus.* To these is now added a sixth species, *Falco oregonus,* new species. All these raptors are very scantily represented.

A few bones of the two living American eagles are identified, as follows:

Haliaeëtus leucocephalus (Linnaeus)

AMNH no. 3469, wing phalanx; AMNH no. 3467A, ungual phalanx; AMNH no. 3486, fragment of ulna; AMNH no. 3485A, fragment of tarsus; UCMP no. 31781, scapula; UCMP no. 31794, pedal phalanx; CIT no. 137/3324, phalanx of hallux; OSC no. 2500/67, fragment of radius; OSC no. 2500/67, 2 ungual phalanges.

Aquila chrysaëtos (Linnaeus)

AMNH no. 3467, fragment of tibiotarsus (2 phalanges bearing this number were wrongly assigned to this species; see *Haliaeëtus*); AMNH no. 3674, fragment of radius; AMNH no. 3470A, symphysis of furcula (cotype of *Aquila sodalis,* now tentatively assigned here).

In addition to these bones of Recent species, there are 6 specimens which represent extinct forms of eagles. These include the type phalanx of *Aquila pliogryps* and type tarsometatarsus of *Aquila sodalis* (casts of which are available), and four pedal phalanges (OSC and AMNH).

Spizaëtus pliogryps (Shufeldt)

Shufeldt (1892, p. 416 and pl. 17, fig. 33) described the type hallux (AMNH no. 3471) of this species under the genus *Aquila,* declaring it to be similar to bones of *A. chrysaëtos* but more slender and slightly longer. The cast of this element now at hand shows that the length and slenderness of the bone, coupled with its general resemblance to bones of *Aquila chrysaëtos,* accord with the characters of specimens in the Los Angeles County Museum collections from Rancho La Brea which have been assigned to *Spizaëtus grinnelli.* The genus *Spizaëtus* is represented today by the crested eagles of South and Central America, as well as by species indigenous to the Orient and South Pacific islands. It is allied with *Aquila* in the subfamily Aquilinae, according to some authorities (see Howard, 1932*b*, p. 3). Two specimens of *Spizaëtus ornatus* from Salvador have been available for comparison. Although the skeleton of the latter is similar to that of *Aquila* in many respects, *Spizaëtus* presents a generally more slender appearance throughout. In *S. grinnelli* from Rancho La Brea, the phalanges are even more slender, relatively, than in the Recent *S. ornatus.*

In this respect the hallux of *pliogryps* agrees with that of *S. grinnelli.* In view of its close resemblance to *S. grinnelli, pliogryps* is here assigned to the genus *Spizaëtus.* That the Oregon fossil is specifically distinct from the California bird is indicated by comparison with over a hundred Rancho La Brea specimens. Distinguishing characters of *pliogryps* are as follows: (1) greater convexity across anterior surface; (2) greater depth through shaft. Length of phalanx, 38 mm.; breadth and depth of shaft, each 6.8 mm.

Three other phalanges in the Fossil Lake material are probably also assignable to *pliogryps.* These are: a second phalanx of digit 2 (AMNH no. 3467B), previously assigned to *A. chrysaëtos;* a second phalanx of digit 3 (AMNH no. 3468A), referred to *Bubo virginianus;* and a first phalanx of digit 3 (OSC no. 2500/68). All are too slender for *Aquila,* though similar in general contour. They closely resemble specimens of *S. grinnelli* from Rancho La Brea, but show greater depth of shaft, reflecting the condition noted in the type hallux.

Hypomorphnus ? sodalis (Shufeldt)

The type of *Aquila sodalis* is a fragmentary proximal end of a tarsometatarsus (AMNH no. 3470), a cast of which is at hand. As indicated in the description of the species (Shufeldt, 1892, p. 417 and pl. 15, fig. 5), the size of this specimen agrees closely with the distal end of tibiotarsus (from the Miocene of Nebraska) described by Marsh as *Aquila* (now *Buteo*) *danana.* Breadth of distal end of tibiotarsus of *B. danana,* 16.9 mm. (Wetmore, 1926, p. 405); breadth of proximal end of tarsometatarsus of *sodalis,* approximately 18 mm. Considering the extent of geologic time between the periods of deposition of the two bones, it is not likely that they represent the same species. At any rate, since the name *sodalis* has been erected for the Oregon tarsus, it should be retained until more concrete proof of its synonymity is forthcoming.

Regarding the generic allocation of *sodalis,* the writer has previously (1932*b,* p. 32) expressed the belief that relationship with *Aquila* was doubtful. The present study confirms this opinion. The position of the internal foramen posteriorly, at the base of the internal calcaneal ridge, and the shortness of the ridge itself resemble the typical buteonine hawks and eagles rather than either *Aquila* or *Spizaëtus.* At first glance the specimen resembles that of a large hawk such as *Buteo regalis* or *B. jamaicensis.* However, the papilla for the attachment of the tibialis anticus muscle is less prominent and more proximally placed, and the posterior surface lacks the marked concavity found in the tarsometatarsus of *Buteo.*

The high position of the papilla for the tibialis anticus (scarcely 4 mm. below the foramina) approaches the condition found in the Pleistocene eagles *Buteogallus fragilis*[7] and *Morphnus woodwardi.* Although the Oregon fossil is similar in size to the tarsus of *fragilis,* the anterior and posterior surfaces and the general contour of the bone are more rugose than in that species. The resemblance is closer to *M. woodwardi,* particularly in the sturdiness of the external calcaneal ridge, but the difference in size and the absence of the multiple foramina posteriorly precludes the possibility of identity with that fossil species. Of the modern species compared,

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[7] As a recent review of characters of this fossil species shows it to be more closely related to *Urubitinga* (now *Buteogallus*) *anthracina* than to *Urubitinga* (now *Hypomorphnus*) *urubitinga,* the species should be known as *Buteogallus fragilis,* rather than *Hypomorphnus fragilis* as recorded in the current Checklist of fossil birds. This relationship holds, also, for the species described as *Urubitinga milleri,* which should now be known as *Buteogallus milleri.*

Hypomorphnus urubitinga is similar in contours, position of papilla, and position of foramina, and represents the closest approach to *sodalis* of any available species; it differs in more slender external calcaneal ridge and in its smaller size. It seems best, however, to place *sodalis* tentatively in the genus *Hypomorphnus* in view of its generally greater resemblance to that genus than to any other with which it has been compared. An exact determination of the generic and specific position of so fragmentary a specimen is almost impossible. Allocation to *Hypomorphnus* at least suggests the general relationship of the fossil more accurately than the previous assignment to *Aquila*.

A pedal phalanx in the Cope collection may also belong to *sodalis*. This is a first phalanx of the hallux, figured by Shufeldt without identification (1913, pl. 19, fig. 191*e*″; AMNH no. 3683). It represents a slender-toed buteonine raptor and, except for larger size, is not unlike the same element in *Parabuteo*. It is relatively longer and more slender than in *Buteo jamaicensis*, or even *Hypomorphnus urubitinga*. It is too small to be associated with *S. pliogryps*.

The symphysis of furcula which Shufeldt placed in this species (AMNH no. 3470A) is much too large for a bird of the size indicated by the type tarsometatarsus, and strongly resembles Recent specimens of *Aquila* and *Spizaëtus*. An exact determination cannot be ventured on so fragmentary a specimen. The curvature is suggestive of *Spizaëtus*, and the bone may belong with *S. pliogryps*. There is considerable variation in this element, however, and certain specimens of *Aquila chrysaëtos* also closely approach the fossil. In view of the marked sturdiness of the bone, allocation to the golden eagle seems reasonable.

Circus cyaneus Linnaeus

The marsh hawk is the only hawk found in the material from Fossil Lake. It is represented by a tarsometatarsus in the University of California collection (UCMP no. 31767) and was recorded by Miller (1911, p. 87). No other specimens of the species have appeared in the collections from the Oregon deposit.

Falco oregonus, new species

(Plate 1, figures 2, 3)

A single falcon bone occurs in the collections from Fossil Lake. It has been compared with a series of Recent falcon skeletons, but, though of the general size of *Falco mexicanus* and *F. peregrinus,* it fails to accord with structural characters of either of these species. It is therefore described as a new species, *Falco oregonus.*

Type. Right carpometacarpus, UCMP no. 31779, collected by Annie M. Alexander party in 1901; Pleistocene, Fossil Lake, Oregon.

Description. Similar in size to *Falco mexicanus,* but distinguished from it by (1) less depression of head internally between pisiform process and process of metacarpal 1; (2) more clearly defined proximal symphysis of metacarpals 2 and 3, seen in posteroexternal view, lacking deep undercut of *F. mexicanus;* (3) posteroexternal margin of internal crest of trochlea not bordered by a well marked depression, but having a small pit only, near the distal tip of the crest.

The smallest available comparable specimen of *F. peregrinus* is 2 mm. longer than the fossil carpus. *Falco peregrinus* is similar to the fossil in contour of internal face (no. 1 above) and approaches it in characters pertaining to the symphysis (no. 2), though the symphyseal area is smaller than in the fossil. The margin of the internal crest of the trochlea (no. 3) is the same in *peregrinus* as in *mexicanus;* the fossil is distinct from both.

Falco columbarius, F. sparverius, and *F. fusco-coerulescens* are all smaller than the fossil. *Falco fusco-coerulescens,* however, is the only species, of all those examined, which approaches it in character of the margin of the internal crest of the trochlea, lacking the marked excavation which characterizes the area in the other Recent forms.

Measurements of type. Greatest length, 53.1 mm.; depth of proximal end, 14.2 mm.; breadth of proximal trochlea, 5.5 mm.; height of process of metacarpal 1, 9.3 mm.

GALLIFORMES

Galliform bones, though numerous in the Fossil Lake deposits, are confined entirely to several species of grouse. About 100 bones of grouse occur in the combined collections at hand and represent 16 or more individual birds. At least three-fourths of the specimens were examined by Shufeldt and classified into six species: *Pedioecetes phasianellus, Pedioecetes lucasi, Pedioecetes nanus, Tympanuchus pallidicinctus, Centrocercus urophasianus,* and *Paleotetrix gilli.*

The occurrence of *Tympanuchus* cannot be corroborated by this study. Of the 8 specimens on which the record was based, 2 humeri are assignable to *Centrocercus urophasianus;* 1 humerus, 2 coracoids, and 2 carpometacarpi are referred to the extinct *lucasi;* and the proximal end of a femur is too fragmentary to be given definite assignment.

In the bones of modern species of grouse, there is a wide range of variation within each species. This fact, coupled with a certain amount of overlapping among the various species, results in some confusion in determining the fossil bones. It is evident from available carpometacarpi that three extinct species of grouse are present, and at least two of these are represented in the tarsometatarsi. However, Shufeldt's unfortunate choice of an ulna as the type of *P. lucasi,* plus the fact that the type material of *P. nanus* (consisting of several specimens but not including an ulna) is divisible into two species, makes it practically impossible to decide which bones shall be called *lucasi,* and which *nanus.* As far as it is possible to determine, the type ulna of *lucasi* could be as well associated with one set of tarsometatarsi as the other. Rather than allow the matter to rest in this state of confusion, however, it seems wise to recognize the tarsometatarsi which Shufeldt referred to *lucasi* as properly assigned. With these are now placed 4 similar (though slightly smaller) specimens which were included with Shufeldt's type material of *nanus.* This leaves only 2 tarsi to represent the latter species. Later discoveries may prove that this association of elements of *lucasi* and *nanus* is erroneous, but it is in as close accord as is now possible with the concept of the species which Shufeldt expressed.

There seems little possibility that either of the sets of tarsometatarsi just discussed belongs with the carpometacarpus described as *Paleotetrix gilli,* unless the latter represents only an abnormal variation, rather than a true species. So far *Paleotetrix* is known only from the type. There are, in addition to the type of *Paleotetrix,* two other groups of carpi which seem suitably associated with the available tarsi of *lucasi* and *nanus* respectively.

Dendragapus lucasi (Shufeldt)

(Plate 1, figure 4)

This species was described (Shufeldt, 1892, p. 414 and pl. 17, fig. 30), on the basis of a complete ulna (AMNH no. 3476), under the genus *Pedioecetes.* Two other ulnae were also assigned. The impossibility of proper determination of the type has been discussed above. The change in generic assignment, therefore, is based on the relationship shown by the 7 tarsometatarsi referred to this species (AMNH no. 3476, 2 specimens, originally referred to *lucasi;* AMNH no. 3475A, 4 specimens, originally referred to *nanus;* OSC no. 2500/74, 1 specimen).

The characters of the tarsometatarsi represent a blending of those found in *Dendragapus* and in *Centrocercus.* The size, general proportions, and anterior contours resemble tarsometatarsi of *Dendragapus,* but the internal edge of the shaft proximally tends to be deeper, and closer to the internal proximal foramen posteriorly, as in *Centrocercus.* The hypotarsus lacks the anteroposterior depth and the prominence of *Dendragapus.* The distal end is more like *Centrocercus* in its symmetry and in the small internal trochlea, but the middle trochlea is broad as in *Dendragapus,* and the position of the internal trochlea is low with respect to the distal end, also as in the latter genus.

Six carpometacarpi are thought to belong to this species (AMNH no. 3475A, 2 specimens, originally assigned to *P. nanus;* AMNH no. 3477A, 2 specimens, previously assigned to *P. phasianellus;* and AMNH no. 3478A, 2 specimens, identified as *Tympanuchus pallidicinctus*). All are similar in size and general characters to *Dendragapus obscurus,* but show relatively less depth of proximal end and less development of the intermetacarpal tuberosity.

Assignment of other elements is uncertain. The humerus which Shufeldt placed with *Tympanuchus* is similar in character to *Dendragapus* and may likely belong with *D. lucasi.* Three complete coracoids (2 left, AMNH no. 3478A, referred to *Tympanuchus;* and 1, OSC 2500/74) have the symmetry and slenderness of *Centrocercus,* but are smaller and lack the junction of the intermuscular lines on the posterior face, thus more closely approximating *Dendragapus.* It seems likely that these bones should be placed with the tarsi referred to *lucasi.* Other elements are not assigned.

Dendragapus nanus (Shufeldt)

(Plate 1, figure 1)

This species, described under the genus *Pedioecetes* (Shufeldt, 1892, pp. 414–415), was based on 6 tarsometatarsi and 2 carpometacarpi (AMNH no. 3475), no one bone being designated as the type. The carpometacarpi are very close to *Dendragapus obscurus* in characters and are now assigned to *D. lucasi.* Four of the tarsometatarsi are also allocated to *lucasi.* This leaves but 2 specimens, both right tarsometatarsi, to represent the species *nanus.* It is therefore suggested that the complete tarsus be designated as the type specimen of this extinct species.

The species *nanus* was originally described only as being of smaller size than *Pedioecetes phasianellus* or *P. lucasi,* with more strongly developed extremities than the former. Further characters now appear which clearly separate *nanus* from the genus *Pedioecetes.* Possibly it belonged to a genus now extinct, but until more can be known of the species, it is placed in *Dendragapus,* a genus with which it shows certain affinities.

Characters of type. Similar to tarsometatarsi of *Dendragapus obscurus* in (1) rounded borders of anterior face of shaft; (2) reduced depression of anterior surface of shaft; (3) short, prominently projecting hypotarsus; and (4) broad median trochlea, and deep internal trochlea of distal end. Distinguished from *D. obscurus* by (1) extreme proximal location of tubercle for tibialis anticus muscle; (2) more symmetrically flared distal end; and (3) relatively more slender shaft.

A carpometacarpus in the University of California collection (UCMP no. 31784) is tentatively assigned to this species. It somewhat resembles the element in *Dendragapus obscurus,* but the external surface of the proximal end is less rugose and the process of metacarpal 1 is more markedly tilted upward.

Pedioecetes phasianellus (Linnaeus)

Of the several bones which Shufeldt identified as of this species, 3 appear to be correctly assigned: a proximal end of right humerus, a right carpometacarpus, and a left tarsometatarsus. All are in the Cope collection (AMNH no. 3477), and possibly represent a single individual. There is some doubt as to the allocation of the larger tarsometatarsus and the coracoid which Shufeldt assigned to this species; the latter bears closer resemblance to *Dendragapus.* Two of the carpometacarpi are now assigned to *D. lucasi;* and the ulna, femur, and tibiotarsi are too fragmentary to determine, although the tibiae do not show the arrangement of tendinal attachments characteristic of *Pedioecetes.*

A coracoid and femur (AMNH no. 3700) in the material which Shufeldt did not classify are tentatively assigned to this species.

Centrocercus urophasianus (Bonaparte)

At least 44 bones are definitely assigned to the sage grouse, and 3 or more individuals are represented. The best specimens of this species are found among those collected for the U. S. National Museum by William Day, in 1883. The others are in the Cope collection (AMNH nos. 3473, 3478B), and in that of Oregon State College (OSC no. 2500/70). Most of the bones are large, indicating male birds.

Paleotetrix gilli Shufeldt

The type carpometacarpus (AMNH no. 3474) is the only specimen known of this extinct genus and species. A cast of the type is available for study.

The species was described (Shufeldt, 1892, pp. 415–416) as smaller than *Centrocercus urophasianus,* but larger than any other existent grouse. This statement is no longer tenable, as there is now at hand a specimen of female sage grouse which is smaller than the fossil. The significant features of *Paleotetrix,* however, lie in its physical contours rather than in actual size. The character stressed by Shufeldt is evident in the cast, namely, the presence of a distinct space between the abruptly terminated posterior border of the external crest of the carpal trochlea and the internal crest of the same. Although in *Pedioecetes* the border of the external crest ends somewhat abruptly, in no species of grouse is the separation between the external and internal crest so marked as in *Paleotetrix.* The condition is actually more closely simulated in the turkeys, chickens, and pheasants. On the basis of the cast alone, however, it is impossible to make the detailed comparisons requisite for complete understanding of its relationships.

List of Galliformes

Species	No. bones	No. individuals
Dendragapus lucasi	20	6
Dendragapus nanus	3	2
Pedioecetes phasianellus	6	2
Centrocercus urophasianus	44	3
Paleotetrix gilli	1	1
Grouse, miscellaneous	33	2
	107	16

GRUIFORMES

With the exception of 1 rail bone, all the 162 gruiform specimens in the Fossil Lake beds are assignable to the coot.

Rallus limicola Vieillot

A small humerus in the Oregon State College collection (OSC no. 2500/76) is the only representative of the rails. The specimen is here assigned to the Virginia rail, and represents a larger than average bird of that species.

Fulica americana minor Shufeldt

Fulica americana was among the first species to be recorded from the Fossil Lake deposits (Cope, 1878). Later Shufeldt (1892, p. 412) described *Fulica minor* based on several small elements for which he found no counterpart in size among comparative Recent specimens of *americana.* The type bone of *minor* is a humerus (AMNH no. 3480; Shufeldt, 1892, pl. 17, fig. 32), the length of which is 62.5 mm. The referred material consists of another humerus, 64 mm. long, 2 coracoids, and a femur. The smaller of the coracoids measures 28 mm. according to the present writer's instrument, although Shufeldt listed it as 27 mm. The other coracoid is broken, but probably would have measured at least 29 mm. long when complete. The femur is 51.5 mm. in length.

These small bones stood apart from the larger specimens of *Fulica* which Shufeldt assigned to *F. americana.* The addition of more fossil bones of coot from the later collections, however, has resulted in a series of over 150 specimens grading from small to large, measurements of which are not markedly dissimilar to those taken on a series of over 70 modern skeletons of *americana* now available. In studying the

Measurements of length of fossil and recent coot bones

	Length (mm.)			No. specimens below mean	No. specimens above mean
	Min.	Mean	Max.		
Coracoid:					
Fossil	28.0	30.7	32.8	5	7
Recent	27.5	30.5	33.9	33	45
Humerus:					
Fossil	62.4	66.6	70.5	4	5
Recent	63.6	69.6	75.6	40	36
Ulna:					
Fossil	55.4	56.9	59.1	3	1
Recent	55.6	61.1	67.8	39	38
Carpometacarpus:					
Fossil	34.7	36.0	38.0	2	2
Recent	36.0	39.5	42.6	43	36
Femur:					
Fossil	51.7	54.5	56.0	1	3
Recent	48.1	52.9	57.5	32	41
Tibiotarsus:					
Fossil	100.0?	....	102.0	(only 2 specimens)	
Recent	82.7	90.5	99.2	32	42
Tarsometatarsus:					
Fossil	52.3	57.4	60.5	1	5
Recent	51.2	56.7	61.8	40	38

accompanying table, it will be observed that, although the coracoid averages nearly the same in the fossil and Recent series, the averages for the fossil humeri, ulnae, and carpometacarpi fall well below those of the Recent bird, with the minimum for each element below the range of the Recent. On the other hand, fossil femora and tarsometatarsi fall entirely within the size range of *americana,* but with slightly greater averages indicated for the fossil. Unfortunately most of the fossil tibiotarsi are incomplete. The one available complete tibia is almost 3 mm. longer than the maximum of *americana,* and another specimen, the length of which can be estimated, is about 1 mm. above the Recent.

From these figures it is strongly suggested that a single species is represented, agreeing with *F. americana* in all structural characters, but having a tendency to relatively shorter wings and, possibly, longer legs than the living coot. It is, of course, possible that these specimens represent only the extremes of range in a more variable Pleistocene bird. On the other hand, it seems illogical that the fossil bones which fall below the minimum of *F. americana* should occur only in the wing elements, the longer ones only in the leg, if the proportions of the bird were the same then as now. Of the total of 161 specimens referred to *Fulica,* 41 are complete and measurable. Eight of these (all wing elements) are smaller than in *F. americana,* 2 (tibiotarsi) are larger. Seventy-six per cent of the specimens are indistinguishable from specimens of *F. americana,* though the total picture of the bird indicates different skeletal proportions. It is no longer possible to recognize *F. minor* as a distinct species in the fossil avifauna, nor, on the other hand, does it seem entirely proper to consider the fossil form to be identical with the Recent bird. The indications are that the living coot is a direct outgrowth of the Pleistocene bird and that we can again apply the principle of the chronocline as explained by Simpson (1943, pp. 170–177) and as already applied in this study in the case of the large grebe (p. 150). It is therefore suggested that the fossil coot be differentiated from the living bird with a trinomial, the name *minor* being used in that position, i.e., *Fulica americana minor.*

CHARADRIIFORMES

Suborder Charadrii: Shore Birds

The previous record of a single shore bird, *Lobipes lobatus,* from Fossil Lake is now increased to a possible six species, represented by from 1 to 4 individuals each.

Numenius americanus Bechstein ?

A fragment of the manubrium of a sternum (OSC no. 2500/91) resembles the long-billed curlew in characters and in size. The assignment to that species is tentative, however, in view of the fragmentary condition of the specimen.

Totanus melanoleucus (Gmelin)

An incomplete humerus (AMNH no. 3490B, assigned by Shufeldt to *Sterna elegans*) resembles that element in the lesser yellowlegs so exactly that it is so assigned, even though the head of the bone is missing. Another specimen of humerus (AMNH no. 3699) also agrees with this species and indicates a second individual.

Limnodromus griseus (Gmelin) ?

A complete ulna in the collection of the California Institute of Technology (CIT no. 137/3314) and a distal end of this element in the Cope collection (AMNH no.

3565B, recorded as *Colymbus nigricollis*) closely resemble the dowitcher. It is difficult, however, to make a definite identification on the basis of the ulna alone in this group, in which there are so many species of similar size and general characters.

Recurvirostra americana Gmelin

A complete humerus in the Cope collection (AMNH no. 3492A), assigned by Shufeldt to *Larus philadelphia,* lacks the deep excavation of the brachial area characteristic of the gulls, and is now found to agree in all respects with Recent specimens of the avocet.

Himantopus mexicanus (Müller)

A second incomplete humerus, listed as *Sterna elegans*[8] (AMNH no. 3490C), undoubtedly represents the stilt. A distal end of tarsometatarsus in the Oregon State College collection (OSC no. 2500/92) may also belong to this species, though it appears to be somewhat less compressed across the trochleae than in the comparative tarsi of *Himantopus* at hand.

Lobipes lobatus (Linnaeus)

This species was recorded on the basis of 3 complete humeri in the Cope collection (AMNH no. 3479). To these are now added 5 more humeri (UCMP 1, no. 31797; OSC 2, no. 2500/93; AMNH 2, no. 3697), and a carpometacarpus (AMNH no. 3697). The 9 specimens represent at least 4 individuals.

Suborder Lari: Jaegers, Gulls, Terns

The suborder Lari is better represented than the foregoing Charadrii. Over 50 specimens are now recognized from the several collections. Shufeldt (1892, pp. 397–400) recorded nine species from bones in the Cope and Condon collections, as follows: *Larus argentatus, L. robustus, L. californicus?, L. oregonus, L. philadelphia, Xema sabini, Thalasseus elegans?, S. forsteri?,* and *Chlidonias nigra.* Some of these are represented in the other collections as well, but others must now be removed from the list.

The identification of *Larus argentatus* was based on a distal end of humerus in the Cope collection (AMNH no. 3491). The somewhat fragmentary proximal part of this bone has now been found in the unidentified material of that collection. With the nearly complete bone at hand, it is obvious that the specimen is not of *Larus,* but closely resembles *Stercorarius,* though of larger size than any existing species of that genus. The bone is therefore now designated as the type of an extinct species, for which the name *Stercorarius shufeldti* is proposed.

Stercorarius shufeldti, new species

(Plate 2, figures 1, 2)

Type. Humerus (AMNH no. 3491), complete except for inner side of proximal end; Pleistocene, Fossil Lake ("Silver Lake" of Cope), Oregon.

Description. Similar to *Stercorarius pomarinus* except for larger size. Length, 139.1 mm.; breadth of distal end, 18 mm.; least breadth of shaft, 8.2 mm.

Discussion. Comparison with *Catharacta skua maccormicki* shows the fossil bone to be equal in length to the skua humerus, but relatively more slender and with sharper contours. The brachial impression is more clearly outlined but less depressed. The characters which distinguish the fossil from *Catharacta* are the same as those which separate the jaegers (*Stercorarius*) from that genus. The fossil may, therefore, be considered a true jaeger of very large size.

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[8] See also *Totanus melanoleucus.*

The possibility that this humerus belongs with the coracoid described as *Larus robustus* has been considered. As the humerus is distinctly that of a jaeger, however, and the coracoid is definitely larine, it does not seem possible that they represent the same bird.

Larus robustus Shufeldt

The type of *Larus robustus* (Shufeldt, 1892, p. 398 and pl. 15, figs. 1, 2) is a complete left coracoid (AMNH no. 3492), a cast of which is at hand for study. Specimens of ulna, tibiotarsus, and tarsometatarsus referred to this species all prove now to be goose.

The type is equaled and even exceeded in length by coracoids of *L. glaucescens*, but is relatively broader across the furcular facet than in any of the gulls available. The anterior edge of the head is markedly extended into a narrow process as in *L. hyperboreus* and several specimens of *L. californicus*. A somewhat similar extension occurs in one specimen of *L. occidentalis*, but the process formed is not so narrow. The extension of this area is much less marked in *L. argentatus*, or *L. glaucescens*, but as it is also small in some specimens of *L. californicus*, it may not be a constant character. The slant of the head and the angularity of the shaft in *L. robustus* bear close resemblance to *L. californicus*, though the bone is of much greater size. Available specimens of *L. hyperboreus* are slightly shorter and more slender.

Comparative measurements of type of Larus robustus and coracoids of related gulls

	a Length* (mm.)	*b* Breadth furcular facet (mm.)	*c* Distance from distal border of scapular facet to head (mm.)	Ratios (%)	
				b to *a*	*c* to *a*
Larus robustus	55.8	16.4	20.5	29.3	36.6
L. hyperboreus	54.5	14.4	19.2	26.4	35.2
L. glaucescens	55.7	14.6	18.5	26.2	33.2
L. californicus	44.6	12.3	15.5	27.8	34.8

*Length measured in a straight line from head to sternal facet, not to internal tip of facet.

Larus oregonus Shufeldt

The species *Larus oregonus* (Shufeldt, 1892, p. 398) was based on 2 humeri, 1 of which was designated as the type (*ibid.*, pl. 15, fig. 3). A cast of this latter (AMNH no. 3494) is now available. The other specimen, if present in the collections at hand, is not labeled *oregonus*.

The type was described as near *Larus delawarensis* in size, but differentiated therefrom on the basis of the less oblique position of the median crest and the greater stoutness of the shaft. With a larger series of modern specimens now available, it is evident that the position of the median crest may vary within a species, and several bones of *delawarensis* are found to coincide with the fossil. The stoutness of the shaft in *oregonus*, however, cannot be duplicated in available specimens of *L. delawarensis* or of the larger *L. californicus*, though a proportionate stoutness does appear in the smaller *L. canus brachyrhynchus*. The type of *oregonus* also agrees with

L. c. brachyrhynchus in being a relatively shorter bone than in either *L. delawarensis* or *L. californicus.* Unfortunately the type specimen is incomplete distally, so that exact measurements are impossible, but the faint indication of the beginning of the brachial depression is evident, and by holding the specimen alongside a modern bone, the length can be visualized. Two other incomplete humeri (AMNH nos. 3495A, 3695), which are here assigned to *L. oregonus,* further substantiate the belief that both shortness and broadness are valid characters of the fossil gull. These specimens lack the proximal end, but the distance from the end of the deltoid crest to the distal end can be measured, and is found to be notably shorter, whereas the shaft is broader, than in Recent bones of *L. californicus* of similar distal breadth.

A structural character in the type of *oregonus,* which seems to differ from specimens of *L. delawarensis* and *L. californicus* but tallies with those of *L. canus,* is the narrowness of the depression below the head anconally. This depression, bounded by the sharp apex of the shaft on one side and by the median crest on the other, tends to narrow almost to a point in the fossil and in *L. canus,* but is more generously rounded in *L. californicus; L. delawarensis* is intermediate in this character between the fossil and *californicus.*

The tarsometatarsi referred by Shufeldt to *oregonus* are now found to be bones of coots. There are, however, 2 other complete and identifiable tarsi in the collections which are larine (AMNH no. 3495A, CIT no. 137/3315). In actual length and stoutness of shaft they agree with measurements of *L. californicus,* but they have the relatively long, straight shaft and narrow ends more characteristic of *L. delawarensis.* As with the humeri assigned to *L. oregonus,* the proportions of these tarsi resemble those of *L. canus brachyrhynchus,* though the fossil bones are much larger. It is altogether probable, therefore, that the tarsi are assignable to *oregonus.*

Two coracoids were also referred by Shufeldt to *L. oregonus* (AMNH no. 3493). One is too fragmentary to assign definitely; the other, a complete left, resembles available coracoids of *delawarensis* in slenderness of proximal end, but has the greater over-all length of *californicus.* The upper part, however, from scapular facet to head, is shorter, relative to total length, than in *californicus, delawarensis,* or *canus.* Four other coracoids (AMNH 3, no. 3495A, previously called *californicus;* OSC 1, no. 2500/86) also display this character of short upper part. It is likely that these coracoids belong to *L. oregonus.*

Measurements of Larus oregonus

Humerus:	
Length from distal extremity of deltoid crest to distal end of bone (mm.)	81.0–83.5
Breadth distal end (mm.)	15.3–16.0
Breadth of shaft (mm.)	6.6– 7.1
Tarsometatarsus:	
Length (mm.)	61.4–64.1
Ratio, breadth proximal end to length (%)	15.2–15.5
Ratio, breadth distal end to length (%)	14.3–15.1
Coracoid (1 measurable specimen only, AMNH no. 3493):	
Length from head to convex part of sternal border (mm.)	42.3
Ratio, breadth furcular facet to length of bone (%)	24.1
Ratio, distance from distal border of scapular facet to head, to length (%)	32.2

Larus californicus Lawrence

A complete left coracoid in the collection from Oregon State College, and 2 coracoids and a proximal end of humerus in the Cope collection, are indistinguishable from comparable modern specimens of California gull. Two incompletely ossified coracoids and fragments of ulna and tibiotarsus are also tentatively referred to this species.

Sixteen other gull bones, comparable in size to *L. californicus,* are present in the collections, many of them young or fragmentary specimens. Although all agree in size with *L. californicus,* some are included in the ranges of *L. delawarensis* and *L. occidentalis* and might likely accord with *L. oregonus* as well, were it possible to identify the entire skeleton of that species. As it is impossible to discern any distinguishing structural characters in these latter specimens, they are left unassigned.

Larus philadelphia (Ord)

Of the smaller gulls, Shufeldt recorded both *Larus philadelphia* and *Xema sabini.* As these species are extremely difficult to distinguish, and Shufeldt's comparative material was scant, his identifications are doubtful. The record of *X. sabini* is based on a single humerus in the Condon collection (UO no. F1679), which is of more slender proportions than available humeri of either the Sabine or the Bonaparte gull. Its general proportions suggest *Sterna elegans,* but the low ectepicondylar process and curving ridge of the anconal surface of the shaft are gull-like. Possibly the specimen represents an extinct form.

One complete and 1 broken humerus in the Cope collection (AMNH no. 3492) bear the name *Larus philadelphia.* The complete bone is not gull, and is discussed in the foregoing section on the Charadrii. The fragment corresponds in size to both *Xema* and *L. philadelphia,* and cannot be distinguished from either.

In addition to the specimens assigned by Shufeldt, there are now at hand a number of other small gull bones. These include: 1 ulna (OSC no. 2500/89); 1 coracoid (AMNH no. 3489A, previously referred to *Sterna forsteri*); and 4 carpometacarpi (OSC 1, no. 2500/89; CIT 2, no. 137/3322–3323; AMNH 1, no. 3481C). The ulna is too small for *Xema sabini,* but agrees in size and placement of papillae with *L. philadelphia.* The coracoid, too, is smaller than in *Xema;* it is too worn to determine the detailed structural characters. The carpometacarpi are difficult to distinguish, although the combination of several characters indicates greater similarity to *L. philadelphia* than to *X. sabini.*

As the trend of all available specimens of small gull is toward *L. philadelphia,* the species is here maintained as listed. *Xema sabini,* however, is omitted.

Sterna forsteri Nuttall

The specimens on which the original tentative identification of the Forster tern was based are 2 coracoids, 2 carpometacarpi, and 1 humerus (all AMNH no. 3489). The humerus is certainly correctly assigned to this species, and one of the coracoids is likely so (the specimen is too young to make a definite determination). The other coracoid, however, has the deep excavation under the furcular facet which is characteristic of the gulls, and has now been referred to *Larus philadelphia.* The 2 carpometacarpi are of ducks.

In addition, a distal end of humerus (OSC no. 2500/90), a fragment of mandible (AMNH no. 3559C), and a carpometacarpus and possibly a young tibiotarsus (AMNH no. 3696) are now referred to *S. forsteri.* Among the specimens in the Cope collection identified as *Thalasseus elegans* is 1 carpometacarpus (AMNH no. 3490A) assignable to the Forster tern. The specimen is 10 mm. shorter than the carpometacarpus of the elegant tern. The other bones assigned to *T. elegans* are not tern, and that species is now eliminated from the list of birds from Fossil Lake.

Chlidonias nigra (Linnaeus)

The humerus identified as the black tern (AMNH no. 3488) agrees with comparable specimens of that species at hand. No additional bones of this species are found in the other collections.

List of Charadriiformes

Species	No. bones	No. individuals
Numenius americanus?	1	1
Totanus melanoleucus	2	2
Limnodromus griseus?	2	1
Recurvirostra americana	1	1
Himantopus mexicanus	2	1
Lobipes lobatus	9	4
Stercorarius shufeldti	1	1
Larus robustus	1	1
Larus oregonus	10	4
Larus californicus	8	3
Larus philadelphia	8	2
Gulls, miscellaneous	17	..
Sterna forsteri	7	2
Chlidonias nigra	1	1
	70	24

STRIGIFORMES

The only species of owl known from Fossil Lake is the horned owl, *Bubo virginianus.* The original record (Shufeldt, 1892, p. 418) was based on a carpometacarpus and pedal phalanx (AMNH no. 3468). The former specimen is correctly assigned, but the phalanx is now found to belong to one of the diurnal raptors, and is discussed under *Spizaëtus pliogryps.*

A distal end of tibiotarsus of this owl is added from the Oregon State College collection (OSC no. 2500/94).

PICIFORMES

The woodpeckers have not been previously listed in the avifauna of Fossil Lake. Among the small specimens of perching birds reviewed for this study by Alden H. Miller, of the University of California Museum of Vertebrate Zoology, one fragment of tibiotarsus (OSC no. 2500/100) proved to be piciform. Miller identifies the bone as that of a flicker and, as in the case of flicker bones from other fossil deposits in California, assigns it to *Colaptes cafer* on geographic grounds. The eastern and western flickers are osteologically so similar that only by comparing large series of skeletons can definite distinctions be drawn.

PASSERIFORMES

Two passerines were recorded from Fossil Lake by Shufeldt, both described as extinct. In the present study, Shufeldt's species are synonymized with Recent forms and another two, or possibly three, modern species are added.

Fifteen bones of Passeriformes are present, but occur in only two of the several collections (AMNH and OSC). These represent approximately 8 individual birds. With the exception of the cast of the type of the raven described by Shufeldt as extinct, all the passerine material has been studied by Alden H. Miller, of the University of California Museum of Vertebrate Zoology. He has kindly submitted a report on the species represented, and the discussion of the small passerine forms is based on his findings.

Corvus corax Linnaeus

A tarsometatarsus of a raven was described by Shufeldt (1892, p. 419) as *Corvus annectens*. The name *annectens* being preoccupied, it was later changed by Sharpe (1909, p. 599) to *Corvus shufeldti*.

The type of this species is the only representative of raven in the Cope collection, nor are any large passerine bones to be found in the other collections from Fossil Lake. A cast of the type is at hand. It represents a bone identical in all respects with *Corvus corax* of today. Shufeldt distinguished his species from the living raven on the basis of small size only. Measurements were given as follows (Shufeldt, *loc. cit.*): length of tarsometatarsus, 61 mm.; transverse diameter of mid-shaft, 4 mm.; transverse diameter of trochlear end, 8 mm.; height of hypotarsus, 4 mm.

Among the comparative specimens of Recent *C. corax* in the Los Angeles County Museum collections is one from Tiajuana, Mexico, which is identical in size with the fossil, and another (for which no exact data as to locality are available) which measures only 60 mm. long; breadth of shaft and distal trochleae agree, proportionately, with the fossil. *Corvus cryptoleucus* is also close to the fossil in length, but appears to be more slender.

Although the bone from Oregon does not now stand apart from *C. corax* as a distinct, smaller species, measurements on a large series of raven tarsi in the Rancho La Brea collection of the Los Angeles County Museum lend support to Shufeldt's theory that the ravens of the Pleistocene tended to be smaller than those of today. The maximum and minimum lengths of 89 tarsometatarsi from the asphalt locality are 69 and 58 mm. respectively, with a mean of 64 mm., whereas of only 10 Recent birds from California and Mexico, the maximum reaches 71 mm. (2 mm. greater than that of the Rancho La Brea series). The minimum of the 10 specimens is 60 mm., the mean 65 mm. Though the range is too close to warrant specific separation, there is a suggestion of a trend toward increase in size from Pleistocene to Recent time.

Euphagus cyanocephalus (Wagler)

The type material of *Euphagus affinis* (AMNH no. 3466, 6 specimens; Shufeldt, 1892, pp. 418–419 and pl. 15, fig. 10) is now referred to the Brewer blackbird. Although the extinct form was described as of more slender proportions than the Recent species, A. H. Miller finds, in his series of modern skeletons now available, specimens which duplicate the fossils in size. The fossil coracoid, in fact, proves to be slightly larger than the average of Recent *E. cyanocephalus,* and the ulnae (3) are of about average size. The humeri (2), although notably slender, agree with the more slender modern specimens.

Icteridae, spp.

The remaining specimens of small passerines (AMNH no. 3709, and OSC nos. 2500/95–99) represent at least two and possibly three additional species. Most of the bones are of blackbird, possibly including both *Agelaius* and *Euphagus.* One small ulna (OSC no. 2500/99) is of either a small blackbird (*Agelaius*) or a cowbird (*Molothrus ater*). A single tibial fragment of larger size (AMNH no. 3709) may be referred to either *Sturnella* or *Xanthocephalus.*

List of Passerines

Species	No. specimens	No. individuals
Corvus corax	1	1
Euphagus cyanocephalus	6	3
Agelaius or Euphagus	6	2
Molothrus ater or Agelaius	1	1
Xanthocephalus or Sturnella	1	1
	15	8

List of Birds from Fossil Lake†

(Extinct species starred)

List according to Shufeldt (1913)	List as now amended	No. bones	No. individuals
Aechmophorus occidentalis *Aechmophorus lucasi?	Aechmophorus oc. *lucasi	828	65
Colymbus grisegena			
Colymbus auritus			
Colymbus nigricollis	Colymbus nigricollis	67	14
*Colymbus parvus	*Colymbus parvus	11	3
Podilymbus podiceps	Podilymbus podiceps	14	4
*Podilymbus magnus			
*Phalacrocorax macropus	*Phalacrocorax macropus	57	7
	Phalacrocorax auritus?	2	1
Pelecanus erythrorhynchos?	Pelecanus erythrorhynchos	2	1
Ardea herodias	Ardea herodias	1	1
*Ardea paloccidentalis			
Botaurus lentiginosus	Botaurus lentiginosus	6	4
	*Stork, species	1	1
*Phoenicopterus copei	*Phoenicopterus copei	18	4
Cygnus buccinator	Cygnus buccinator	31	3
Cygnus columbianus			
*Cygnus matthewi			
*Cygnus paloregonus	*Sthenelides paloregonus	70	3
Branta canadensis	Branta canadensis	112	13
Branta bernicla	Branta bernicla	6	2
*Branta hypsibata	Branta hypsibata?‡	1	1
	Goose, species (large)	6	2
*Branta propinqua	*Branta propinqua	20	5
Anser albifrons	Anser albifrons	16	5
*Anser condoni			
Chen hyperborea	Chen hyperborea	28	5
Chen caerulescens			
	Chen rossii	7	3
	*Anabernicula, species	32	7
Anas platyrhynchos	Anas platyrhynchos	15	4
Anas acuta	Anas acuta	11	4

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†Specimens which could be given only general classification are not indicated in this list. They are, however, included in the totals recorded in the discussion.

‡Probably a synonym of *Chen hyperborea.*

List of Birds from Fossil Lake—*Continued*

List according to Shufeldt (1913)	List as now amended	No. bones	No. individuals
Anas carolinensis	Anas carolinensis	20	5
Anas discors			
Anas cyanoptera?	Anas cyanoptera	3	2
Mareca americana	Mareca americana	35	15
Spatula clypeata	Spatula clypeata	28	7
Aix sponsa			
Nyroca americana?	Nyroca americana	17	8
Nyroca collaris?	Nyroca collaris?	2	1
Nyroca valisineria			
Nyroca marila			
Nyroca affinis?	Nyroca affinis	7	2
Glaucionetta islandica			
Charitonetta albeola	Charitonetta albeola	2	1
Clangula hyemalis	Clangula hyemalis	10	2
Histrionicus histrionicus			
Polysticta stelleri			
	Melanitta perspicillata	3	1
Erismatura jamaicensis	Erismatura jamaicensis	57	11
Lophodytes cucullatus			
Mergus merganser	Mergus merganser	3	2
Mergus serrator	Mergus serrator	19	3
*Aquila sodalis	*Hypomorphnus ? sodalis	2	1
*Aquila pliogryps	*Spizaëtus pliogryps	4	1
Aquila chrysaëtos	Aquila chrysaëtos	3	1
Haliaeëtus leucocephalus	Haliaeëtus leucocephalus	10	2
Circus cyaneus§	Circus cyaneus	1	1
	*Falco oregonus, n. sp.	1	1
*Pedioecetes lucasi	*Dendragapus lucasi	20	6
*Pedioecetes nanus	*Dendragapus nanus	3	2
Tympanuchus pallidicinctus			
Pedioecetes phasianellus	Pedioecetes phasianellus	6	2
Centrocercus urophasianus	Centrocercus urophasianus	44	3
*Paleotetrix gilli	*Paleotetrix gilli	1	1
	Rallus limicola	1	1
Fulica americana *Fulica minor	Fulica americana *minor	161	23
	Numenius americanus?	1	1
	Totanus melanoleucus	2	2
	Limnodromus griseus?	2	1
	Recurvirostra americana	1	1
	Himantopus mexicanus	2	1
Lobipes lobatus	Lobipes lobatus	9	4
Larus argentatus	*Stercorarius shufeldti, n. sp.	1	1
*Larus robustus	*Larus robustus	1	1
Larus californicus?	Larus californicus	8	3
*Larus oregonus	*Larus oregonus	10	4
Larus philadelphia	Larus philadelphia	8	2
Xema sabini			
Sterna forsteri?	Sterna forsteri	7	2
Thalasseus elegans			
Chlidonias nigra	Chlidonias nigra	1	1

§This species was omitted from Shufeldt's list, though it had been previously recorded by Miller (1911).

List of Birds from Fossil Lake—*Continued*

List according to Shufeldt (1913)	List as now amended	No. bones	No. individuals
Bubo virginianus	Bubo virginianus	2	1
	Colaptes cafer	1	1
*Corvus shufeldti	Corvus corax	1	1
*Euphagus affinis	Euphagus cyanocephalus	6	3
	Sturnella or Xanthocephalus	1	1
	Agelaius?	6?	2?
	Molothrus ater?	1	1

Conclusions

The species represented in the deposits of Fossil Lake indicate an avifauna in general like that to be found living today about inland lakes of Oregon and California. Even the extinct forms show relationships which suggest adaptation to similar ecologic conditions. The large extinct cormorant, for example, was more closely allied to the inland-breeding *Phalacrocorax auritus* than to the strictly coastal forms. At first thought, the presence of a flamingo in Oregon seems incongruous. Flamingos thrive today, however, in zoological parks in temperate zones of North America, and may likely have had a more extended natural distribution in the past. Although one of the American species, *Phoenicopterus ruber,* is a bird of the islands and seacoast, the Chilean and African species are at home about inland lakes and streams. The characters of the fossil species suggest closer relationship with the inland forms.

The only species which seems entirely out of place is the large jaeger, *Stercorarius shufeldti.* Jaegers are not known to occur today within many miles of the locality, nor would members of this oceanic group be expected to visit this area except accidentally. As only one specimen occurs, the bird was possibly a straggler, uncommon to the region even in the Pleistocene.

Incompletely ossified bones of young birds give evidence of the nesting of certain of the species on or near the shores of the lake. Outstanding among these are the extinct cormorant (*Phalacrocorax macropus*) and flamingo (*Phoenicopterus copei*), as well as the Lucas western grebe (*Aechmophorus occidentalis lucasi*) and the lesser coot (*Fulica americana minor*). Young gull bones may represent both the extinct *Larus oregonus* and the California gull (*Larus californicus*). Additional young specimens belong to small grebe, tern, merganser, and ruddy duck, and other forms may be represented among the bones too incompletely formed to classify.

Of the other Pleistocene assemblages of the west coast, only the first fauna described for McKittrick, California (Miller, 1925) approaches that of Fossil Lake in character. The similarity is not marked, however, for, as has been pointed out by Miller (*ibid.,* p. 310), the McKittrick site appears to have represented an area of more restricted water, shallower as well as less extensive, with more muddy, or grassy borders. Whereas 91 per cent of the birds at Fossil Lake were water birds, only 67 per cent were so associated in the McKittrick fauna. Divers, which were exceedingly abundant in the Oregon deposit, were limited to a few bones in the California assemblage, whereas the reverse is true of the storks, herons, cranes, and shore birds, which would be associated with grassy or muddy areas adjacent to the water.

Another outstanding difference between the Oregon and the California deposits is the greater abundance of raptorial birds in the McKittrick beds. This cannot be considered an indication of greater numbers of raptors living in the McKittrick region, but is associated with the fact that the deposit, like those of Rancho La Brea and Carpinteria, was one of asphaltum, which, in the Pleistocene, acted as a trap for animals of all kinds and attracted numbers of predators to the region to prey on the luckless creatures thus ensnared.

This method of accumulation of the large California Pleistocene assemblages makes difficult any exact correlation of age with the Fossil Lake deposit. Criteria which have been used in comparing the asphalt localities with one another cannot be expected to give an accurate picture when applied to the Fossil Lake assemblage, which accumulated under normal lacustrine conditions. The number of individuals of extinct species in the Fossil Lake avifauna is but 15 per cent of the total number of individuals estimated for that assemblage. In the McKittrick deposit, where the extinct raptorial forms are represented in great abundance, the number of individuals of extinct species runs as high as 27 per cent (DeMay, 1941, p. 58) of the total number of individuals,[9] and at Rancho La Brea, from 33 to 49 per cent of the individuals represent extinct forms (Howard and Miller, 1939, p. 44).

Although normally a comparison of the relative abundance of individuals representing extinct and Recent forms would seem to be more significant than a comparison of numbers of species alone, in this instance the latter comparison seems preferable. Though the superabundance of raptors in the asphalt deposits is reflected in the species count, it is less exaggerated than when dealing with individual specimens. Calculated on the basis of species count, the proportions are as shown in the table on page 194.[10]

Making allowance for the difference in mode of accumulation, the evidence derived from the avifauna indicates that the Fossil Lake occurrence closely coincides with the Rancho La Brea deposits in age, but is slightly older than the McKittrick beds.[11]

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[9] For these percentages, the passerine bones, where present, are omitted from the total count. Because of their small size, they have been overlooked in the excavation of some deposits, whereas in others special care was taken to preserve them. This has naturally resulted in a variability in totals not in keeping with actual occurrence.

[10] This method of correlation is open to criticism, especially in dealing with very late Pleistocene or early Recent deposits, where extinct species may have continued on, but with very scant numbers of individuals. Rancho La Brea pit 10 is a case in point, the proportion of extinct species being 19 per cent, whereas a count of individuals shows only 5 per cent extinct (Howard and Miller, 1939, p. 44).

[11] For a complete discussion of the earlier views concerning the age of the Fossil Lake occurrence, see Elftman (1931, p. 3).

Locality	Percentage of extinct species relative to total number of species*
McKittrick, CIT loc. 138	16.4
McKittrick, UC fauna no. 1	20.5
McKittrick, UC fauna no. 2	22.0
Fossil Lake	25.0†
Rancho La Brea pit 3	25.5
Rancho La Brea pit 4	30.2

*See footnote 9.

†Miller's (1925, p. 312) previous estimate of 37 per cent was based on the older lists of avian species, which included several more extinct forms than are now recognized.

LITERATURE CITED[12]

Cope, E. D. 1878. Descriptions of new Vertebrata from the Upper Tertiary and Dakota formations. Bull. U. S. Geol. and Geog. Surv. Terr., vol. 4, pp. 379–396.

——— 1889*a*. The vertebrate fauna of the *Equus* beds. Amer. Naturalist, vol. 23, pp. 160–165.

——— 1889*b*. Silver Lake of Oregon and its region. Amer. Naturalist, vol. 23, pp. 970–982, pls. 40–41, 1 text fig.

Demay, Ida S. 1941. Quaternary bird life of the McKittrick asphalt, California. Carnegie Inst. Wash. Pub. 530, III, pp. 35–60, 4 text figs.

Elftman, Herbert O. 1931. Pleistocene mammals of Fossil Lake, Oregon. Amer. Mus. Nov. No. 481, 21 pp., 10 text figs.

Howard, Hildegarde. 1932*a*. A new species of cormorant from Pliocene deposits near Santa Barbara, California. Condor, vol. 34, pp. 118–120, 1 text fig.

——— 1932*b*. Eagles and eagle-like vultures of the Pleistocene of Rancho La Brea. Carnegie Inst. Wash. Pub. 429. iii+82 pp., 29 pls., 3 text figs.

——— 1936. Further studies upon the birds of the Pleistocene of Rancho La Brea. Condor, vol. 38, pp. 32–36.

——— and Alden H. Miller. 1939. The avifauna associated with human remains at Rancho La Brea, California. Carnegie Inst. Wash. Pub. 514, III, pp. 39–48, 4 text figs.

Marsh, O. C. 1870. Notice of some fossil birds from the Cretaceous and Tertiary formations of the United States. Amer. Jour. Sci., ser. 2, vol. 49, pp. 205–217.

McCornack, Ellen C. 1920. Contributions to the Pleistocene history of Oregon. Univ. Oregon Leaflet Ser., Geol. Bull. VI, no. 3, pt. 2, pp. 3–23.

——— 1928. Thomas Condon, pioneer geologist of Oregon. v+355 pp., 9 ills. University Press, Eugene, Ore.

Miller, Loye. 1911. Additions to the avifauna of the Pleistocene deposits at Fossil Lake, Oregon. Univ. Calif. Publ., Bull. Dept. Geol., vol. 6, pp. 79–87, 3 text figs.

——— 1925. Avifauna of the McKittrick Pleistocene. Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 15, pp. 307–326, 3 text figs.

Ross, Roland. 1935. A new genus and species of pigmy goose from the McKittrick Pleistocene. Trans. San Diego Soc. Nat. Hist., vol. 8, pp. 107–114, 6 text figs.

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[12] A more complete bibliography of literature concerning Fossil Lake may be found in Elftman (1931).

Russell, Israel C. 1884. A geological reconnaissance in southern Oregon. U. S. Geol. Surv. 4th Ann. Rept., pp. 431–464, 3 pls., 10 text figs.

Sharpe, R. Bowdler. 1909. A hand-list of the genera and species of birds. Vol. 5. xx+694 pp. British Museum, London.

Shufeldt, R. W. 1891*a*. On a collection of fossil birds from the *Equus* beds of Oregon. Amer. Naturalist, vol. 25, pp. 359–362.

——— 1891*b*. Fossil birds from the *Equus* beds of Oregon. Amer. Naturalist, vol. 25, pp. 818–821.

——— 1892. A study of the fossil avifauna of the *Equus* beds of the Oregon desert. Jour. Acad. Nat. Sci., Philadelphia, vol. 9, pp. 389–425, pls. 15–17.

——— 1913. Review of the fossil fauna of the desert region of Oregon, with a description of additional material collected there. Bull. Amer. Mus. Nat. Hist., vol. 32, pp. 123–178, pls. 9–43.

Simpson, George Gaylord. 1943. Criteria for genera, species, and subspecies in zoology and paleontology. Ann. New York Acad. Sci., vol. 44, pp. 145–178.

Sternberg, Charles H. 1909. The life of a fossil hunter. xiii+286 pp., 50 ills. Henry Holt & Co., New York.

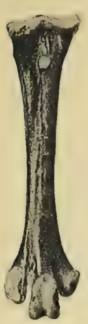
Waring, G. A. 1908. Geology and water resources of a portion of south-central Oregon. U. S. Geol. Surv. Water Supply Paper 220, 86 pp., 10 pls., 1 text fig.

Wetmore, A. 1924. Fossil birds from southeastern Arizona. Proc. U. S. Nat. Mus., vol. 64, art. 5, pp. 1–18, 9 text figs.

——— 1926. Description of a fossil hawk from the Miocene of Nebraska. Ann. Carnegie Mus., vol. 16, pp. 403–406, pl. 38.

——— 1937. A record of the fossil grebe, *Colymbus parvus,* from the Pliocene of California, with remarks on other American fossils of this family. Proc. Calif. Acad. Sci., vol. 23, pp. 195–201, 15 text figs.

PLATES



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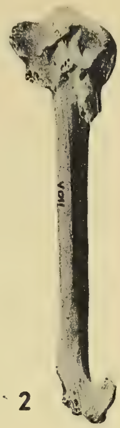

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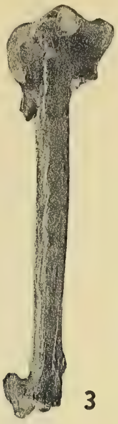

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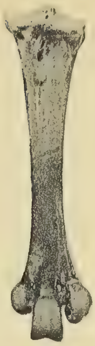

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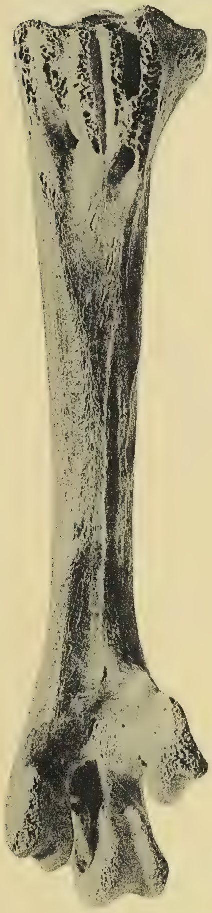

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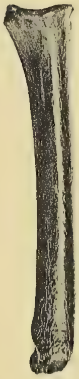

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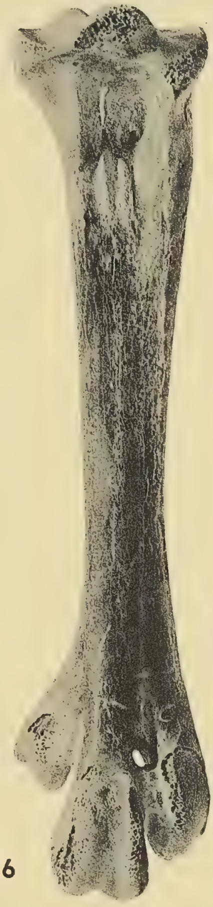

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Fig. 1. *Dendragapus nanus* (Shufeldt). Type, right tarsometatarsus (AMNH no. 3475). Anterior view.

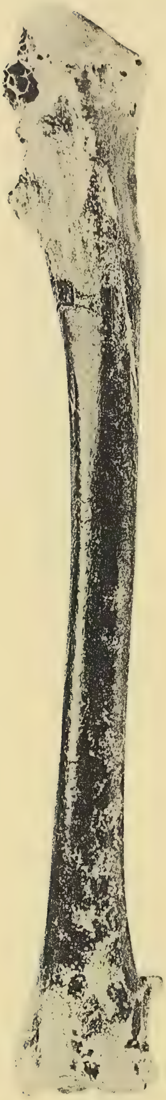
Figs. 2, 3. *Falco oregonus,* n. sp. Type carpometacarpus (UCMP no. 31779). Fig. 2, internal view; fig. 3, external view.

Fig. 4. *Dendragapus lucasi* (Shufeldt). Left tarsometatarsus (AMNH no. 3476). Anterior view.

Figs. 5, 6. *Sthenelides paloregonus* (Cope). Type tarsometatarsus (AMNH no. 3552a). Fig. 5, posterior view; fig. 6, anterior view.

Fig. 7. Stork, species. Pedal phalanx (UCMP no. 31769).

Pleistocene, Fossil Lake, Oregon Natural size



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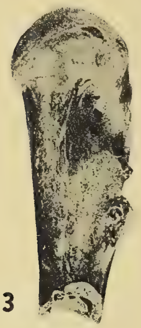

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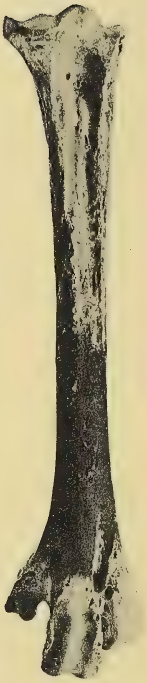

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Figs. 1, 2. *Stercorarius shufeldti,* n. sp. Type humerus (AMNH no. 3491). Fig. 1, anconal view; fig. 2, palmar view.

Fig. 3. Goose, species (large). Coracoid (OSC no. 2500/44). Internal view.

Fig. 4. *Branta hypsibata* (Cope)? Probable type tarsometatarsus (AMNH no. 3539b). Anterior view.

Pleistocene, Fossil Lake, Oregon Natural size

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